Astro Students Surf Into Cyberspace

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How Old is the Universe?

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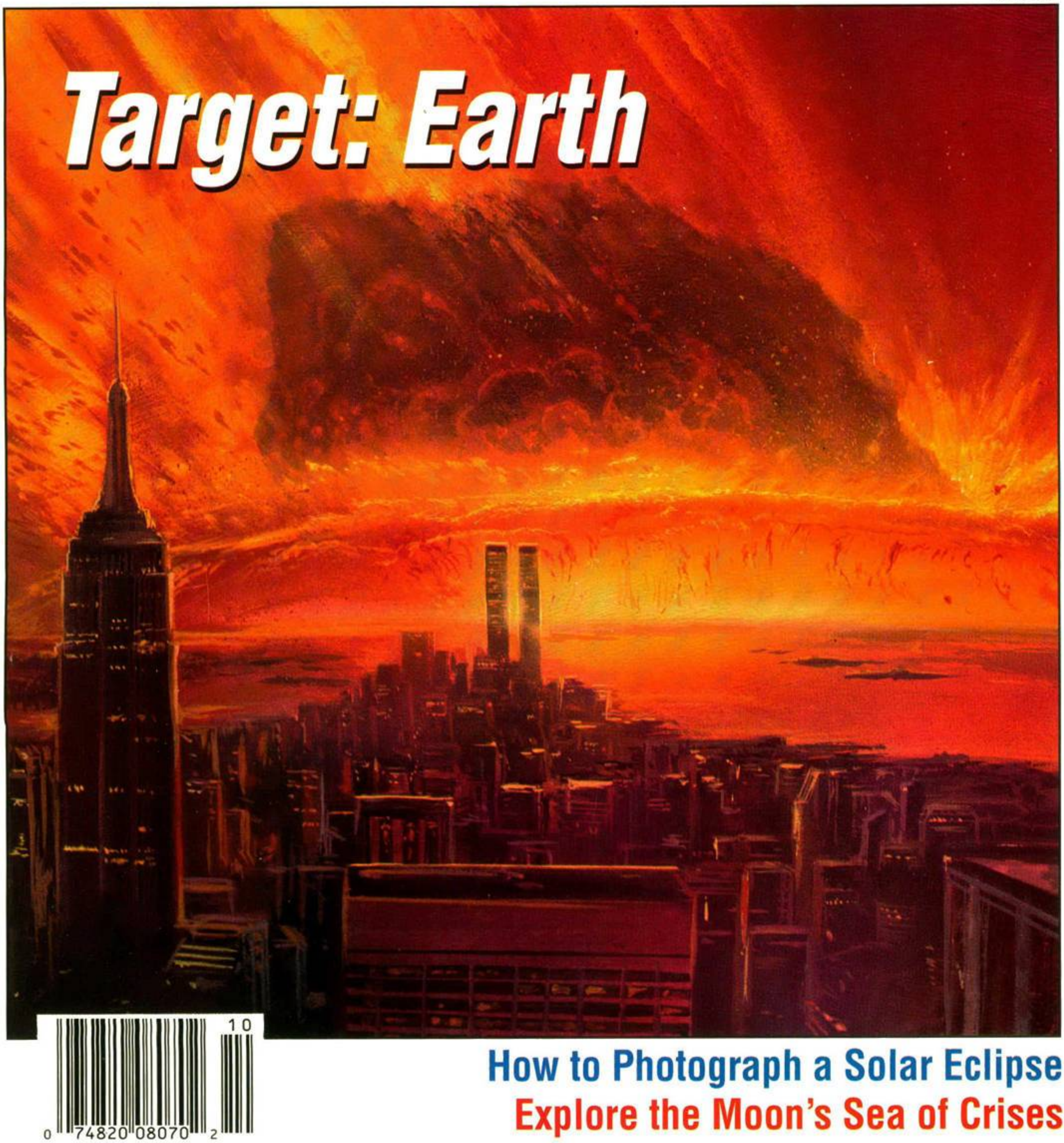
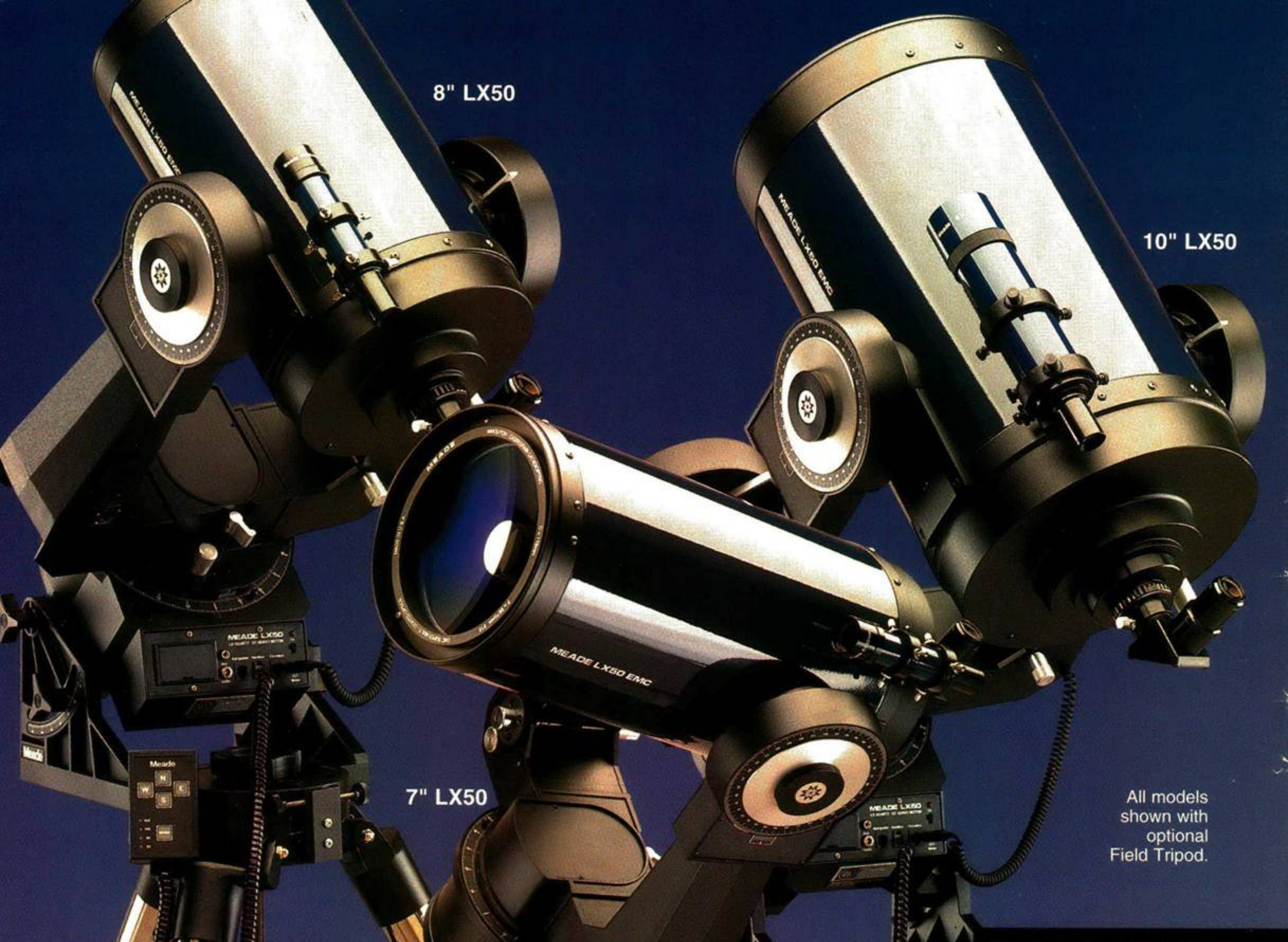


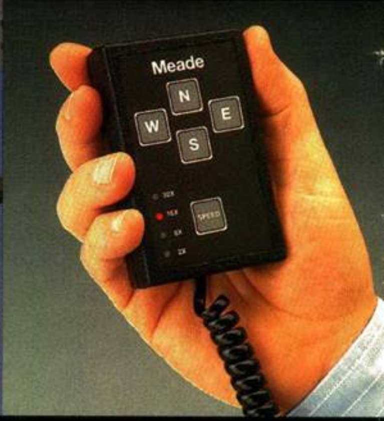
How to Photograph a Solar Eclipse

Explore the Moon's Sea of Crises


8" LX50
10" LX50
7" LX50

All models shown with optional Field Tripod.

The standard-equipment LX50 hand control permits 4 dual-axis speed rates, from 2x photo-guide to 32x microslew.


Meade
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Meade 7" f/15 Maksutov tube assemblies are available for separate purchase. Each includes a flat mounting plate for attachment of the tube to alternate mountings.

Meade Instruments has just reduced the cost of telescope technology.

New Meade® LX50 models combine advanced electronic and mechanical systems with legendary Meade optical performance— all at the most affordable prices ever.

■ **Battery-powered, completely cordless operation!** Meade LX50 models operate for more than 50 hours from four AA-size batteries inserted through the telescope's control panel. Or use the standard-equipment 25 ft. cord to power the telescope directly from any auto cigarette lighter plug.

■ **Standard-equipment Declination Motor and Hand Controller permit 4-speed dual-axis capability:** Plug the hand controller *(see inset photo, facing page)* into the LX50 control panel and you're ready for full dual-axis drive capability at any of 4 photo-guide or microslew speeds: 2x, 8x, 16x, or 32x, plus quartz-controlled sidereal-rate tracking in R.A. Switch speeds instantly using the speed-control button on the hand controller. Dual-axis drive rate is indicated by a red LED.

Complete per specifications below:

8" LX50 Schmidt-Cassegrain	**$1195.**
10" LX50 Schmidt-Cassegrain	**1495.**
7" LX50 Maksutov-Cassegrain	**1595.**
Variable-Height Field Tripod	**295.**
7" Maksutov-Cassegrain Tube Assembly, only	**1195.**

Packing and shipping in the 48 states: 8"—$105; 10"—$145; 7"—$125; 7" Tube Assembly—$65.

Prices shown are suggested U.S. national mail-order prices. For further details on Meade LX50 models, send for your free copy of **Meade Bulletin 500** or send $3.00 for the complete 76-page **Meade 1995 General Catalog.**

SPECIFICATIONS: 7", 8", and 10" LX50's—Each complete telescope includes 8" or 10" f/10 Schmidt-Cassegrain or 7" f/15 Maksutov-Cassegrain optical tube assembly with EMC super multi-coatings; heavy-duty LX200-type fork mount; 5.75" LX worm gear system in R.A., multi-function control panel display on the drive base; DC servo Declination motor; manual and electric slow-motion controls on both axes; setting circles on both axes; keypad handheld controller; 4-speed drive controls on both axes; battery compartment accepting four (user-supplied) AA-size batteries; 25 ft. power cord for telescope operation from 12v. auto cigarette lighter plug; 6 x 30mm (7' and 8" models) or 8 x 50mm (10" model) viewfinder with crosshairs; 1.25" diagonal prism; MA25mm multi-coated eyepiece (1.25"); standard equatorial wedge with elevation scale, bubble level, and azimuth control; complete operating instructions.

LX50 7" Maksutov-Cassegrain 8", 10" Schmidt-Cassegrains

■ **Multi-function control panel:** Including jacks for CCD autoguiders/imagers; electric focuser; and for the standard-equipment Declination motor. A North-South switch permits telescope operation anywhere in the world.

■ **Legendary Meade optical systems:** The same EMC super multi-coated optics as provided with Meade LX200 models; optics that approach the image resolution of the finest apochromats.

■ **Massive LX200-type fork mounts:** Meade LX50 mounts are manufactured of the exact same virgin aluminum castings as Meade LX200 Schmidt-Cassegrains. Massive, rigid mountings that include the Meade LX worm-gear drive system with low periodic error for advanced photographic or CCD imaging applications. *No competing mid-priced equatorial mountings even come close.*

NEW MEADE 7" f/15 MAKSUTOV-CASSEGRAIN!

Now for the first time, serious lunar, planetary, and double-star observers can enjoy all the high-resolution advantages of the finest, large-aperture Maksutov optics, at affordable prices. Manufactured entirely at the Meade Irvine, California, facility, this newest addition to the Meade telescope line is designed for the most demanding applications. With its long f/15 focal ratio, the Meade 7" Maksutov presents exquisite, textbook-quality diffraction images against extremely high contrast black-sky backgrounds. Used as a deep-space observing tool, the telescope yields a level of image corrections normally associated with expensive multi-element lens systems. Meade 7" Maksutovs are available in either the LX50 format described on this page or in the LX200 configuration, discussed elsewhere in this issue.

STANDARD-EQUIPMENT FEATURES: MEADE LX50 MODELS

	7"	**8"**	**10"**
Optical Design	Maksutov-Cassegrain	Schmidt-Cassegrain	Schmidt-Cassegrain
Primary Focal Ratio	f/2.5	f/2	f/2
Overall Focal Ratio	f/15	f/10	f/10
Primary Mirror Dia.	7.62"	8.25"	10.37"
Super Multi-Coatings	yes	yes	yes
Optical Tube Dims.	9.1" x 19.5"	9.1" x 16"	11.75" x 22"
Viewfinder	6 x 30mm	6 x 30mm	8 x 50mm

All models:

Fork Mountings	Heavy-duty; dimensions same as LX200 fork mounts.
Bearings	R.A.: 4" and 2.25" ball bearings; Dec.: Nylon.
Setting Circle Diams.	Declination: 6"; Right Ascension: 8.75".
R.A. Drive System	4-speed, microprocessor-controlled 12v. DC servo motor; 5.75" worm gear.
Dec. Drive System	4-speed, 12v. DC servo motor.
Dual-Axis Drive Rates	2x, 8x, 16x, 32x sidereal.
Slow-Motion Controls	manual and electric, both axes.
R.A. Tracking Rate	sidereal rate, quartz-controlled.
Input Power	6v. DC (4 x AA-size batteries), *or* 12v. DC auto cigarette lighter plug.
Hand Controller	5 directional/speed pushbuttons with red LED speed indicators.
Wedge Latitude Range	23° to 64° (7", 8"); 15° to 64° (10").

ADVANCED PRODUCTS DIVISION

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World's Leading Manufacturer of Astronomical Telescopes for the Serious Amateur

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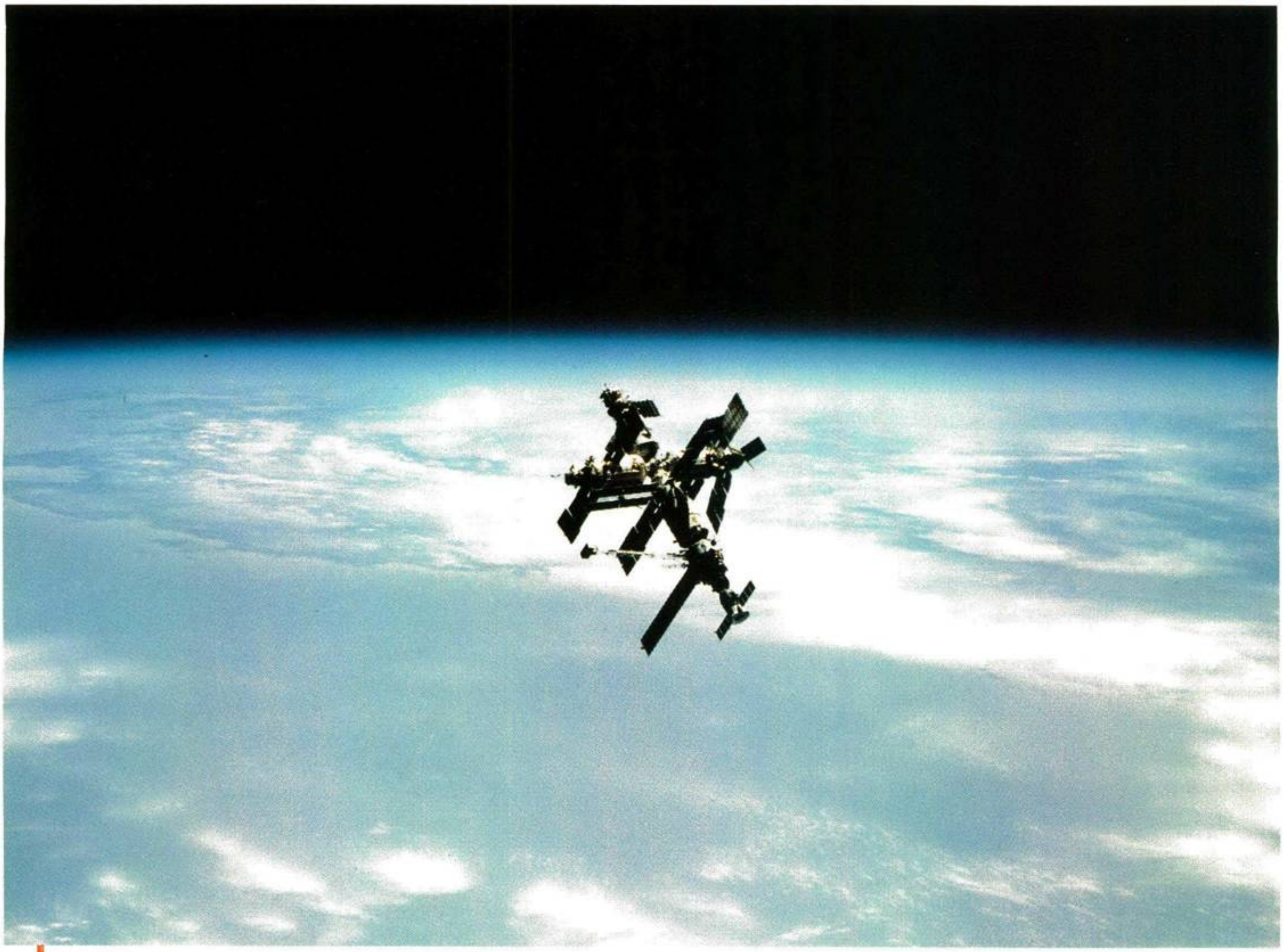

NASA

23 In the News: Rendezvous in Space

COVER 34

Target: Earth

Could a cosmic missile bring down civilization? Yes — the only real question is whether there's an asteroid or comet with Earth's name on it. By David Morrison.

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A Milestone in Fornax

The Hubble Space Telescope turns its eye toward the Fornax Cluster of galaxies in hopes of pinning down the size and age of the universe. By Ken Croswell.

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Students in Cyberspace

Telescopes, planetariums, museums, and even NASA are just a mouse click away from teachers and pupils in the high-tech classrooms of the '90s. By David Bruning.

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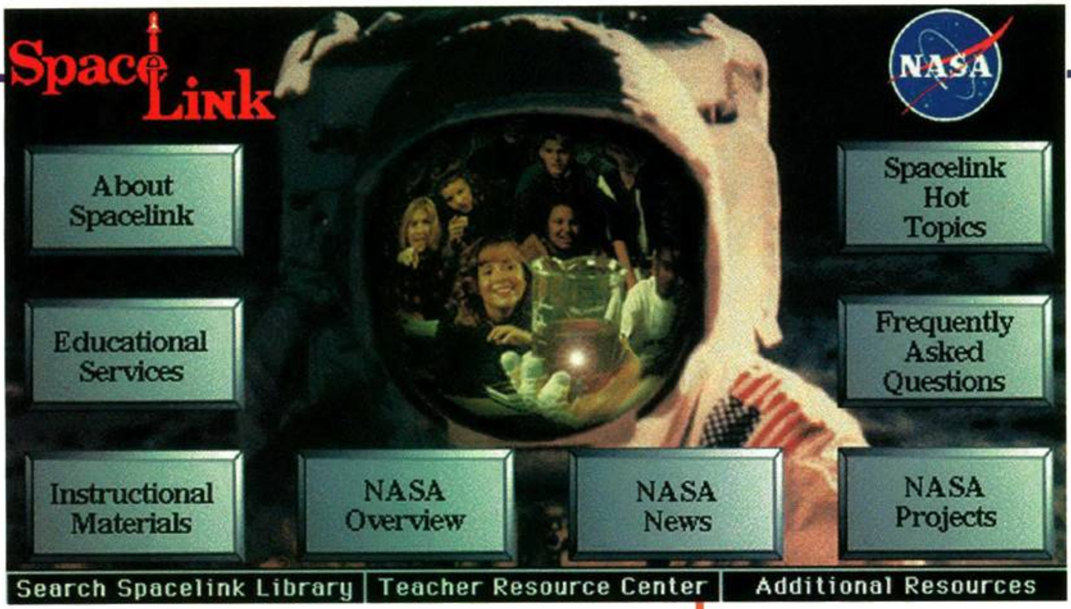
Sky Almanac

October offers Venus' return as the evening star and Mercury's as the morning star, but the highlight of the month could be the finest meteor shower of 1995. By Deborah Byrd and Rick Shaffer.

ON THE COVER

MAYHEM IN MANHATTAN ensues following the impact of a large asteroid. Researchers no longer debate whether such a catastrophe can happen, only when it will occur. For more on the threat to Earth and what's being done about it, see page 34.
Illustration by Robert Eggleton.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Wallace Baldwin

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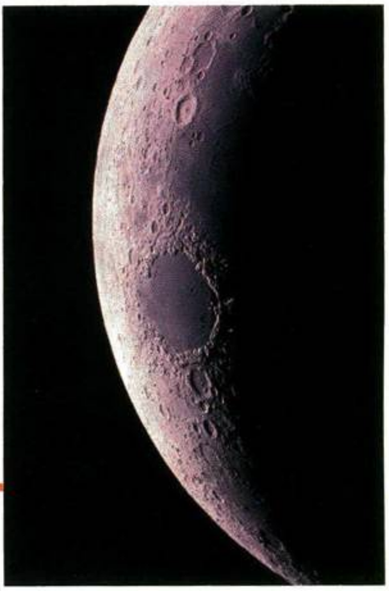
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76 Sunrise on the Moon
This simple computer program can tell you where the Sun is rising on the Moon, throwing lunar features into sharp relief. By David Bruning and Richard Talcott.

80 Shoot the Solar Eclipse
Capturing beautiful portraits of the eclipsed Sun is easier than you might think. Here's some expert advice on how to do it. By John Shibley.

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BEHIND THE SCENES

What — Me Worry?

Next time you stroll into a McDonald's or a Burger King, pause a moment to count the staff before you step up to place your order. According to planetary scientist David Morrison (page 34), your favorite burger joint probably has more people behind the counter than the world has observers hunting for asteroids that might hit our planet. If that's not a scary thought, tell me a scarier.

Almost nobody takes seriously the danger of an impact on Earth from an extraterrestrial body. That's a regrettable fact, but it's easy to see where the head-in-the-sand attitude comes from. After all, the chance of a big impact happening in your lifetime or mine is quite remote.

But it's not negligible. The threat of a big meteorite strike on Earth hits humanity in one of its weakest points: realistic risk assessment. The chart on page 40 paints the picture. Unlike other risks we face daily from events that are fairly likely but which have only a small number of casualties, an asteroid strike has a low probability of occurring, but a simply whopping butcher's bill if it ever happens. The impact of an object only 500 yards across would have worldwide consequences severe enough to affect the life of every person on Earth no matter where it hit. And there is absolutely nothing to prevent such a strike occurring today. What's worse, we don't even know if there's a big object out there right now with our name on it.

It's not like we've never been warned. The Tunguska impact of 1908 was a small-scale version of what could happen and that impact bashed flat hundreds of square miles of Siberian forest. And the stunning impact of Shoemaker-Levy 9 on Jupiter in 1994 showed what an average comet could do. So what has to happen to make an event like this real enough for people to take a few serious precautions? I don't want to exaggerate the threat: We're not talking about the extinction of all life on Earth or even of humanity itself, though both are possible. No, what we're talking here is a civilization-ending event. One whose consequences are so bad that civilization is blown back to the Stone Age — or further. That's bad enough to my mind.

Sixty-five million years ago, the dinosaurs were struck unawares and all perished. They had an excuse of sorts; we don't. Need it be said? We live in one solar system. What happens to Jupiter one year could happen to us in any other. We humans need to be a little more mindful of our own neighborhood — and not treat the task of asteroid detection and defense as casually as we treat burger-flipping.

Sincerely,

Robert Burnham
Editor
rburnham@astronomy.com

LETTERS

Mount Graham Debate

I must take exception to claims made by Roger Angel, Peter Strittmatter, Bruce Walsh, and Nick Woolf in "The Saga of Mt. Graham" (Forum, July 1995).

1. "A small band of environmental activists seek to derail telescope construction." In fact, opposition to the project is widespread. Groups such as the Nature Conservancy and the Humane Society oppose the project.

2. "Mt. Graham is far from pristine . . ." and "a mere 8.6 acres . . ." The ancient spruce-fir forest of the highest elevations comprises a relic Pleistocene-epoch ecosystem of 600 acres that have never been logged or otherwise seriously disturbed by humans. Thus, 8.6 acres is significant, especially considering the "edge-effect" of canopy opening, noise, etc. that could well extend the impact area to an estimated 40 acres.

3. "No distinct species have been found on the mountain." "Distinct species" is an obfuscating phrase that does not change the fact that no less than 18 kinds of plants and animals have been identified on Mt. Graham that exist nowhere else.

4. "One of the prime observing sites in the continental United States." Mt. Graham receives 35 inches of annual rainfall and has been shown to have only 54 percent suitable nights for astronomy. An NOAO study listed 38 better continental U.S. sites.

5. "In 1993 the Apache Tribal Council took a neutral position." Three times previous to the so called "neutrality resolution" the Tribal Council passed resolutions opposing the project, and on June 13, 1995, voted 5-to-1 to "whole-heartedly rescind" the "neutrality resolution" and reaffirm their continuing opposition to the Mt. Graham telescopes.

Astronomy should be environmentally benign. The beauty and wonder of the

(continued on (page 14)

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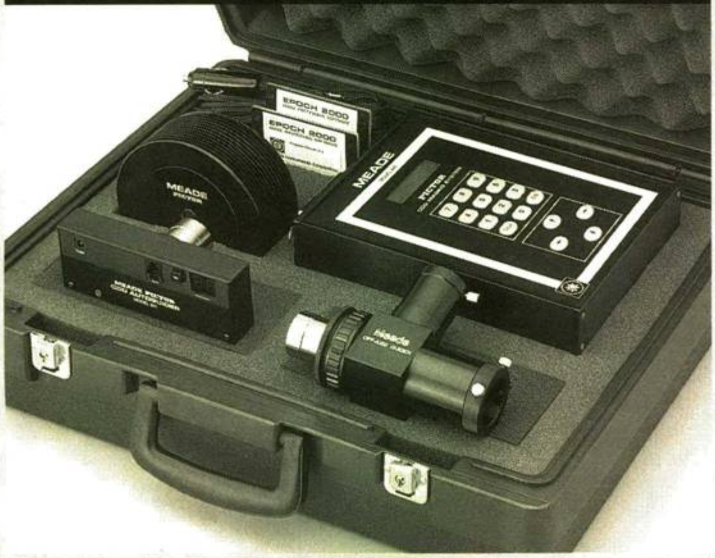
The Audit Bureau

FREE! $800 CCD Equipment System!

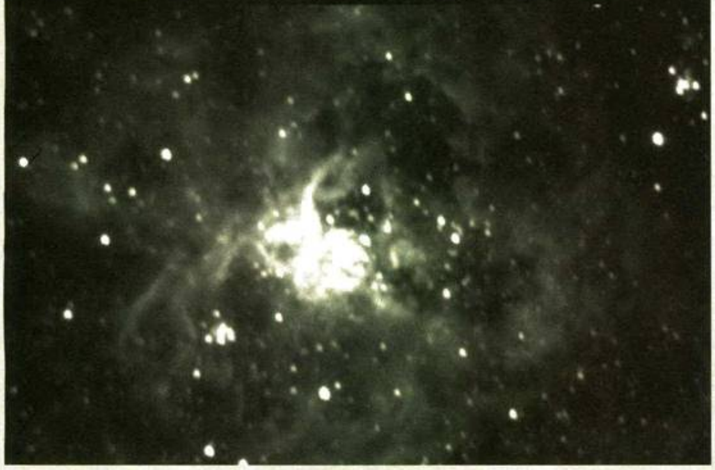
Now, for a limited time, when you purchase a Meade Pictor 416 or 1616 CCD imager at the regular price, **we'll include an $800 Meade CCD Equipment System—everything you need for advanced CCD imaging—absolutely FREE!** Purchased separately, the CCD Equipment System is priced at $807 and includes these important products:

Meade Pictor 201 Autoguider: Allows completely automatic guiding of your Pictor camera during CCD imaging or your 35mm camera during long-exposure astrophotography.	**$395.**
Meade CCD Off-Axis Guider System: Complete with adapters for 1.25" eyepiece holders and for Schmidt-Cassegrain rear-cell threads. Use with the Pictor 201 on guide stars to 10th-magnitude.	**119.**
Meade CCD Image-Orientation Adapter: Threads into the Off-Axis Guider and permits precise image orientation on the CCD chip.	**35.**
Meade Epoch 2000ip Image Processing Software: Professional Windows-based image processing that permits the enhancement and analysis of CCD images using the most advanced techniques, including dynamic scaling, histogram equalization, image convolution, unsharp masking, median filtering, RGB merging, and more.	**199.**
Meade Foam-Lined Carrying Case (19" x 14" x 7"): Provides for secure storage and transport of your Pictor 416 or 1616 CCD imager as well as all items of the CCD Equipment System described above.	**59.**
Total price of all items if purchased separately:	**$807.**

The Meade Pictor 416 CCD Imaging Camera is packed, at no additional charge, with the **Meade $800 CCD Equipment System** during the period of this special offer.

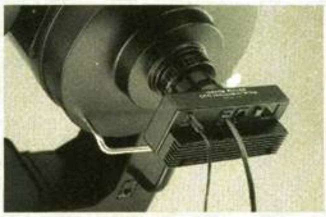


The Tarantula Nebula (NGC 2070): Pictor 416; a 4-minute exposure by Steven Williams with the Meade 10" f/10 LX200 Schmidt-Cassegrain telescope.



Pictor 201 Autoguider: For flawless, ultraprecise autoguiding during long-exposure astrophotography or CCD imaging. Automatically locks on to guide stars as faint as 10th-magnitude and makes all required dual-axis corrections. Results in perfectly guided astrophotographs or CCD images during even the longest of exposures. Completely self-contained; no host PC required. **$395.** + $10 packing & shipping in 48 states.

Pictor 208 Autoguider/Imager: For an amazingly low price, the 208 gives impressive imaging capability even to the novice. On telescopes of 4" aperture and larger, the Pictor 208 yields very satisfying results and, in addition, is a full-capability autoguider, containing the exact same autoguider hardware and software as the Pictor 201, above. The 208 incorporates the Texas Instruments TC-255 microchip, by far the largest, highest-resolution chip available in any CCD unit in its price range. **$795.** + $15 P & S



Pictor 216 CCD Autoguider/Imager: Identical in operation and size to the 208, the Pictor 216 includes a 16-bit A/D converter for 65,536 brightness levels. The result is a level of image quality only obtainable on competing units that sell for almost twice the 216's price. Combining high-resolution imaging with low dark current, the Pictor 216 satisfies the long-term CCD imaging requirements of the majority of serious amateurs. **$1295.** + $15 P & S

Pictor 416 CCD Autoguider/Imager: Armed with the powerful Kodak KAF-0400 CCD microchip, the Pictor 416 is the most advanced high-resolution CCD system available under $5000. And, with its standard-equipment SCSI interface, the 416 can full-frame download in *one second!* The Pictor 416 is a powerful CCD system on any telescope; attached to a Meade LX200, its capabilities are truly awesome. The auto-mosaic feature, for example, permits the imaging of an arbitrarily large sky area **automatically** on user command. **$2495.** + $25 P & S

MEADE
PICTOR

Pictor 1616 Autoguider/Imager: For professional-level applications the Pictor 1616 utilizes the Kodak KAF-1600 microchip, one of the largest (13.80 x 9.20mm) CCD chips in commercial production. Identical in pixel density and dark current to the 416, but with *four times* the chip area, the 1616 permits the imaging of very large sky areas: a sky area of 23' x 15' with an 8" f/10 Schmidt-Cassegrain, almost one-half the lunar surface in a single exposure. The 1616 is the finest CCD imaging system available at under-$10,000. **$6995.** + $40 P & S

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PICTOR

The special Meade CCD Equipment System offer is effective beginning July 20, 1995, at participating Meade dealers in the U.S.A. and Canada. *This offer is valid until further notice and may be withdrawn at any time.* ■ All prices shown are suggested U.S. national mail-order retail prices, exclusive of sales taxes or credit card charges, if applicable. ■ For safety reasons AC-powered personal computers should be used indoors only. ■ The Meade brochure ***CCD Imaging Made Simple*** is available free of charge, or send $3.00 for the 76-page **Meade *1995 General Catalog.***

AUTHORIZED U.S. MAIL-ORDER DEALERS

ASTRONOMICS, Norman, OK, Orders: 800-422-7876; Information: 405-364-0858
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Orders & Information: 818-505-8424
CITY CAMERA, Dearborn, MI, Orders: 800-359-5085; Information: 313-846-3922
FOCUS CAMERA, Brooklyn, NY, Orders: 800-221-0828; Information: 718-436-6262
LUMICON, Livermore, CA, Orders: 800-767-9576; Information: 510-447-9570
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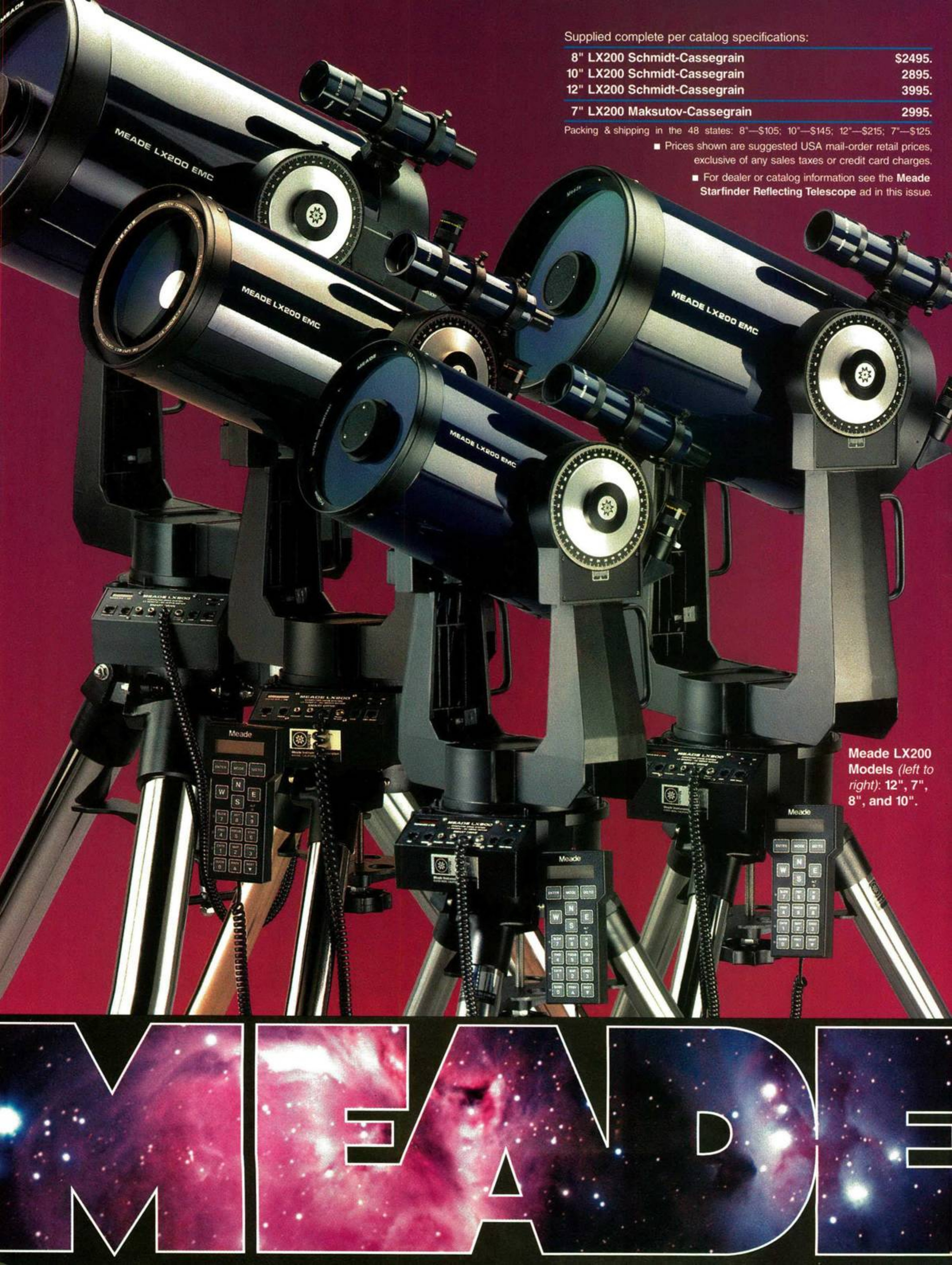

Supplied complete per catalog specifications:

8" LX200 Schmidt-Cassegrain	**$2495.**
10" LX200 Schmidt-Cassegrain	**2895.**
12" LX200 Schmidt-Cassegrain	**3995.**
7" LX200 Maksutov-Cassegrain	**2995.**

Packing & shipping in the 48 states: 8"—$105; 10"—$145; 12"—$215; 7"—$125.

- Prices shown are suggested USA mail-order retail prices, exclusive of any sales taxes or credit card charges.
- For dealer or catalog information see the **Meade Starfinder Reflecting Telescope** ad in this issue.

Meade LX200 Models *(left to right)*: **12", 7", 8", and 10".**

THE TELESCOPE STANDARD OF THE WORLD.

In virtually every country in the world where serious telescopes are sold, more Meade® LX200's are sold than all competing models combined.

In school, college, and university teaching programs, among visual observers, astrophotographers, CCD imaging specialists, and advanced amateurs worldwide, Meade LX200's are, far and away, the Number One choice. No other telescopes offer the LX200's combination of state-of-the-art, standard-equipment features:

- **Superb Optics:** LX200 optical imaging capabilities are a legend in the industry; we regularly receive reports to the effect that optical performance approaches that of a fine *ED* apochromatic lens.
- **Tracking Precision:** The LX200's permanently-programmable Smart Drive™ routinely achieves a tracking periodic error of 5 arc secs. or better, the standard for large observatory instruments.
- **Automatic GO TO Capability:** Meade LX200's are *the only commercial telescopes ever manufactured* that automatically GO TO any input R.A. and Dec. to a precision of *one arc-minute or better.*
- **Meade High-Precision Pointing™** is so precise that it permits the positioning of *every* selected object on *every* commercially-available CCD chip *every* time, automatically. Photographing or CCD imaging faint objects *at or past the visual observing limit (e.g.,* the planet Pluto or a supernova in an 18th-magnitude galaxy) is not only practical, but routine.
- **9-Speed Dual-Axis Electronics:** Electronics that cover every possible contingency of telescope positioning—from 2x photoguiding, to 32x image centering, to 8°/sec. slewing across the sky, as well as 6 other dual-axis drive speeds in between.
- **Field Portability and Operation:** No other telescopes of such sizable apertures and incredible capabilities transport so readily for field operation. Field set-up requires only minutes, and the optional #1812 Electronic DC Adapter (a compact 4 oz. unit) allows for field powering of the telescope directly from an auto cigarette lighter plug.

New Meade 7" LX200 Maksutov-Cassegrain: Now the advanced amateur can obtain the optical perfection of a large-aperture Maksutov, combined with the electronic elegance of an LX200. For details call or write for your free copy of **Meade Bulletin 500.**

- **64,350-Object onboard database:** Imagine having 64,350 celestial objects at the tip of your finger: 64,350 objects—galaxies, nebulae, globular clusters, double stars, planets, objects of virtually every description—*that you can center in the telescopic field just by entering and pressing GO TO on the hand controller.* The Meade 64,350-object library includes an incredible array of phenomena, virtually a lifetime of deep-space study, even for the advanced observer:

12,921	galaxies from the Uppsala General Catalog; the complete UGC catalog.
7,840	objects from the New General Catalog; the complete NGC catalog.
5,386	objects from the Index Catalog; the complete IC catalog.
21,815	variable stars; the complete listing from the General Catalog of Variable Stars to mag. 16.6
15,928	stars from the Smithsonian Astrophysical Observatory (SAO) catalog of stars brighter than 7th magnitude.
351	alignment stars for the LX200 telescope.
110	Messier objects; the complete listing.
8	major planets from Mercury to Pluto.
64,359	objects, total

LX200
SCHMIDT-CASSEGRAINS

SPECIFICATIONS: 7", 8", 10", and 12" LX200's—Each complete telescope includes 8" or 10" (f/6.3 or f/10) or 12" f/10 Schmidt-Cassegrain or 7" Maksutov-Cassegrain optical tube assembly with EMC super multi-coatings; heavy-duty fork mount with 4" polar ball bearing, dual-axis 5.75" worm gears, and multi-function control panel display on the drive base; manual and electric slow-motion controls on both axes; keypad handheld controller with digital readout display, permanently programmable Smart Drive™, 9-speed drive controls on both axes (7-speed on 12"), High-Precision Pointing, and GO TO controller; 64,350-object onboard celestial software library; 25 ft. power cord and adapter for telescope operation from 115v.AC (for field operation from any 12v. auto cigarette lighter plug, use the Meade #1812 Electronic DC Adapter, a 4-oz. unit available optionally); 8 x 50mm viewfinder with crosshairs; 1.25" diagonal prism (7", 8", 10") or 2" diagonal mirror with 1.25" adapter (12"); Series 4000 Super Plössl 26mm eyepiece; standard field tripod (7", 8", 10") or giant field tripod (12"); complete operating instructions.

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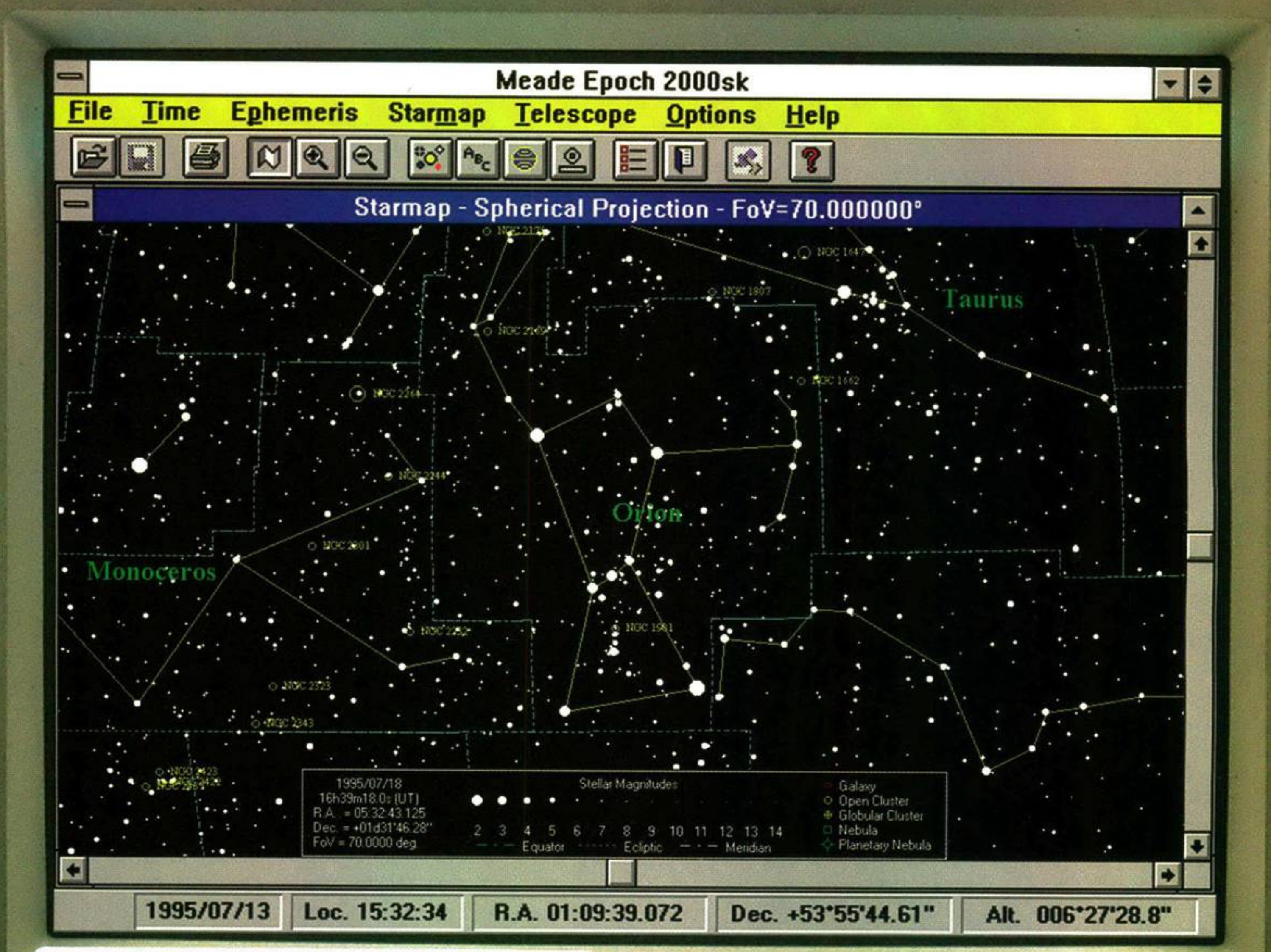
Meade Epoch 2000sk
File
Time
Ephemeris
Starmap
Telescope
Options
Help
Starmap - Spherical Projection - FoV=70.000000°
NGC 1647
NGC 1807
Taurus
NGC 2169
NGC 1662
NGC 2264
NGC 2244
Orion
NGC 2301
Monoceros
NGC 2252
NGC 1981
NGC 2323
NGC 2343
NGC 2423
Stellar Magnitudes
2 3 4 5 6 7 8 9 10 11 12 13 14
Equator
Ecliptic
Meridian
Galaxy
Open Cluster
Globular Cluster
Nebula
Planetary Nebula

1995/07/18
16h39m18.0s (UT)
R.A. = 05:32:43.125
Dec. = +01d31'46.28"
FoV = 70.0000 deg

1995/07/13 | Loc. 15:32:34 | R.A. 01:09:39.072 | Dec. +53°55'44.61" | Alt. 006°27'28.8"

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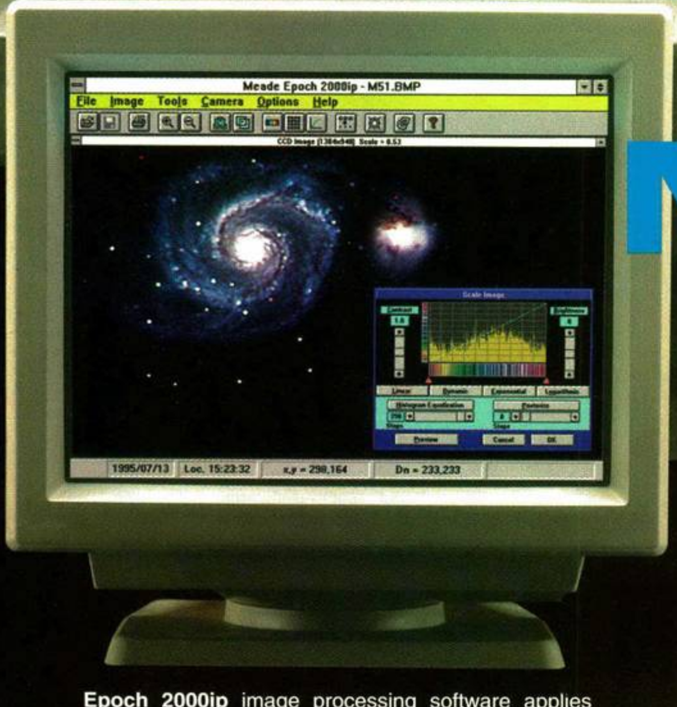
Meade Epoch 2000ip - M51.BMP
File
Image
Tools
Camera
Options
Help
Scale Image
Preview
Cancel
OK

1995/07/13 | Loc. 15:23:32 | x,y = 298,164 | Dn = 233,233

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Meade Bulletin 2000, with complete details on Epoch 2000 astronomical software, is available free of charge from authorized Meade dealers or directly from Meade Instruments. ■ Prices shown are suggested U.S.A. mail-order retail prices, not including any applicable sales taxes or credit card charges.

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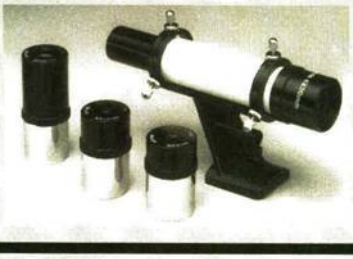

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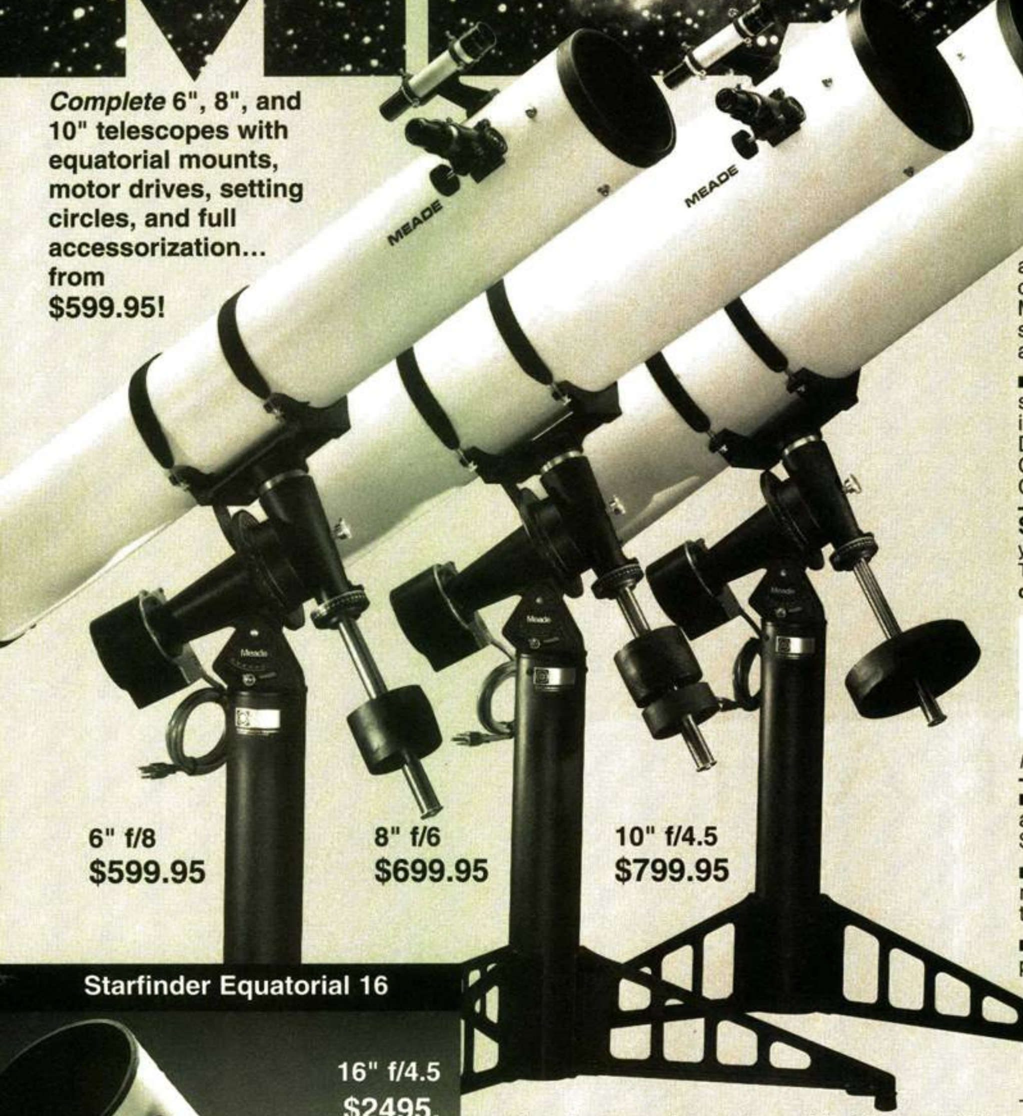

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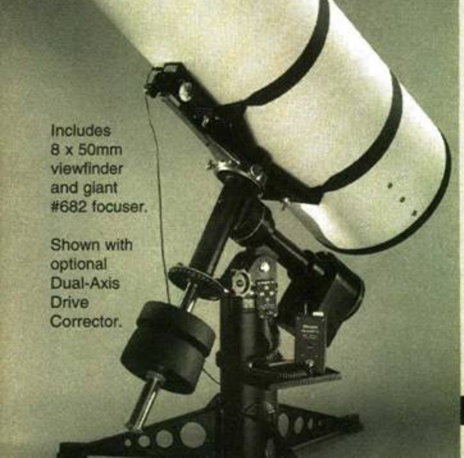
Starfinder Equatorial 16



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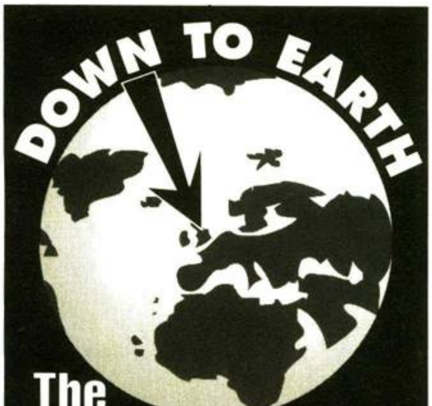

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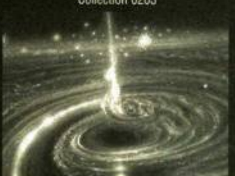

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LETTERS

night sky is an inspiration, but observatories should not be built in rare ecosystems. — *Leo Mellon, Tucson, Arizona*

Roger Angel, Peter Strittmatter, Bruce Walsh, and Nick Woolf reply:

Mr. Leo Mellon's letter cites many of the "facts" used by observatory opponents. Unfortunately it always takes a lot more effort to correct misinformation than to propagate it.

The reality is that most organizations do not pursue the Mt. Graham controversy actively but allow their names to be used to demonstrate solidarity. The real effort is coming out of a small band of activists based in Phoenix. It is always the same people who are present at demonstrations and court hearings, and who draft letters to the press. Opinion polls show that an overwhelming majority of the citizens of Arizona and especially Graham County support the project.

A glance at the aerial photographs published with our article should provide ample proof that Mt. Graham is hardly pristine. Where is the 600-acre undisturbed relic Pleistocene-epoch ecosystem and how is it distinguished from its surroundings? Certainly it is not near the observatory, no part of which is more than 200 yards from preexisting roads and firebreaks. Much of the "ancient" spruce fir forest burned in the late 1600s, but it recovered well — as it obviously has done many times since the Pleistocene. Many tens of acres of Mt. Graham forest are destroyed naturally each year by fire — areas that far exceed the 8.6 acres of the observatory and road combined. The observatory clearing is simply not biologically significant. It is hard to understand why only telescopes raise concern, but not the access highway, the 250,000 visitors per year, the 93 summer homes, the transmitter stations, or the bible camp.

The 18 subspecies are often cited but not named. They appear to come from a generous reading of the first observatory environmental impact study carried out by the University of Arizona Office of Arid Land Studies. They consist of plants, insects, and mollusks, most of which can be found outside the 3,500-acre study area. None appears to have its main habitat in the spruce/fir forest near the observatory. There is not a shred of evidence that any would be materially effected by the 8.6-acre observatory.

The astronomical conditions on Mt. Graham are typical of other prime southwestern observatory sites. It has virtually the same amount of cloud-free time, but with less water vapor in the line of sight due to its higher altitude, and far less light pollution. Yes, a study by two NOAO staff members to "predict" the seeing from topographical maps ranked Mt. Graham as 38th out of 59 sites. The study did not, however, include cloud cover or light pollution as criteria, and it ranked Mt. Hopkins as 57th, where the Smithsonian's Multiple Mirror Telescope enjoys superb seeing. Observatory opponents know all this but continue to cite this study in an effort to mislead the public.

The San Carlos Apache Tribal Council has changed its views several times in the last decade, expressing no interest prior to 1990 and official neutrality between 1993 and 1995. During the latter period, repeated but unsuccessful attempts were made by members of the Apache Survival Coalition to reverse the neutrality resolution. In June 1995, three members of the Council voted to oppose the observatory while four abstained out of an 11-person Council.

One of the saddest things about the saga of Mt. Graham is the continued campaign of deliberate misinformation aimed at killing the project. This has obscured the fact that environmental protection of Mt. Graham has increased enormously as a result of the observatory project — including the cessation of logging. We continue to hope that the future will bring a more rational approach so that real issues can be addressed and solved — and so that the great tradition of astronomical research in the desert southwest can continue.

Sharing the Sky

I agree wholeheartedly with Bob Cook's letter (June 1995) about sharing his enthusiasm for the sky with others, particularly children. I would recommend that he and others seek out local councils of the Boy and Girl Scout groups and volunteer as a merit badge counselor on astronomy. Most of ASTRONOMY's readers would qualify for this task.

Readers could also offer to run a star party at a scout camp to share their love of the stars with the kids. Anyone volunteering their time to help our young people will find great satisfaction in knowing they have helped mold a child's future.

"Change the life of a child and you will change the world," someone once said. Your local Boy and Girl Scouts of America chapter is listed in the phone book. — *Allen Hefner, Valley Forge Council, Boy Scouts of America, bsawdmem@aol.com*

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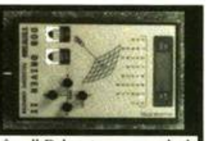

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LETTERS

I disagree with Mr. Cook's assertions about astronomy clubs being composed of "old guys." I'm 54 and have been in our club for 37 years. Only three members have been in the club longer, and they're in their 70s and 80s. Most of our members are in their 30s and 40s.

If some "old guys" don't want to answer "dumb questions," so be it. Perhaps they feel that anyone with a real interest in the hobby should be willing to put forth the effort to find the answers on their own. — *Rodger W. Gordon, Nazareth, Pennsylvania*

I read with interest Mr. Cook's somewhat angry remarks about astronomy clubs. Here's my response: Dear Bob, I don't know what types of clubs exist in your state, but here in Iowa the true spirit of amateurs mingles with a touch of para-professionalism.

The goals of the Des Moines Astronomical Society are educating the public — especially children — and meeting to share thoughts and observations. We offer free public observing nights, complete with discussions and follow-up viewing in our observatory. Guests are encouraged to view as many objects as they wish.

Our membership consists predominantly of young adults, about as many women as men, as well as a growing number of children. There are a few "old guys," whose experience we value, particularly during public viewing nights.

We are hardly unique. And as an educator, I urge you to reconsider the value of amateur astronomy clubs. Please, don't make sweeping generalizations in retaliation for a bad experience. I recommend joining a club for just a year. If your viewpoint does not change, then I invite you to come visit us here in Iowa. We would welcome you with open arms. — *Laurre Bremen, Des Moines Astronomical Society, Inc., Indianola, Iowa*

Correction

The address and phone number supplied with Kiva Scientific's binocular chair (June, New Products) should have read 4357 30th Street, San Diego, CA 92104-1313; (619) 492-8432, fax (619) 583-4342. ☐

ASTRONOMY welcomes feedback. Send your letters to ASTRONOMY Letters, P.O. Box 1612, Waukesha, WI 53187, or use letters@astronomy.com on Internet. Letters may be edited for length and clarity.

Mystery in Gemini

by Gordon Bond

In 1859, James Buchanan was in the White House, John Brown seized Harper's Ferry, and Oregon joined the Union. Two years later America would hear the first shots of its bloody Civil War. Meanwhile, across the Atlantic in Hereford, a county town in west England near Wales, a 52-year-old reverend and amateur astronomer published *Celestial Objects for Common Telescopes.*

This two-volume work by Thomas William Webb became a classic source of information about the wonders of the universe for generations of amateurs. Its popularity prompted the printing of four editions by Webb and another two editions after Webb's death. Volume one of *Celestial Objects* starts with an introduction to telescopes and methods of observation. The rest of the first volume describes comets, meteors, the Sun, the Moon, and the planets through Neptune, which was discovered in 1846.

The second volume deals with what backyard astronomers today call deep-sky objects. Listed by constellation, it catalogs many double and multiple stars, stars with remarkable spectra, variable stars, and nebulae and groups. Amateur astronomers will find much here that is still worth observing.

Though some of the information it contains is now of historical rather than practical value, it remains one of my favorite sources. Reading through it provides a reflection of the man who wrote it and the perception of the universe in a bygone era.

For example, in the introduction to the wonders of Cygnus, Webb wrote, "Planetary nebulae are also closely associated with this part of the Milky Way, and it is a highly suggestive fact that while the Nova Aurigae and other novae turned into planetary nebulae, we have no case of a nebula condensing into a star." Astronomers now know that certain types of nebulae, such as the Great Orion Nebula (M42), do indeed condense into stars.

Webb used a variety of telescopes to make his observations. His first had a fluid achromat. In early 19th-century England, opticians could not afford the import taxes on the German-made flint glass used to correct the improper focusing of colors by a crown glass objective lens. Instead they made lenses from liquids such as hydrochloric acid and carbon disulfide.

His second scope was a 3.7-inch refractor with a focal length of 5 feet. In 1859, Webb acquired a 5.5-inch refractor made by Alvan Clark. Five years later, he mounted to the side of this scope an 8-inch reflector with a 6-foot focal length. The mirror, as was standard in those days, had a coating of silver instead of aluminum to reflect light. His last telescope, which he used from 1866 on, was a 9.3-inch silvered reflector.

These scopes provided the observations for the various editions of *Celestial Objects.* Webb recorded his notes about the Sun, Moon, planets, stars, and nebulae in four large notebooks, ending with 3,463 observations that are interspersed with exquisite drawings. The earliest observation is of Jupiter and dates to December 1834, eight years after he studied mathematics at Oxford and became ordained at the great cathedral in Hereford. Viewing red stars would be a favorite pastime of Webb's, and many of his observations became part of the *Red Star Catalogue* by John Birmingham, an Irish amateur astronomer.

Daniel McGlaun, Jr.

WEBB'S MYSTERIOUS OBJECTS hide 2° northwest of Pollux, the northernmost of the two brightest stars in Gemini.

While thumbing through the sixth edition (1917) of Webb's book in search of objects to look for with my 10-inch Dobsonian, I came across an intriguing entry that was somehow uncharacteristic of the rest. It's tucked away in the listings for Gemini, between the entries for the bright cluster M35 and NGC 2392 (now known as the Eskimo nebula). Webb's entry is far too brief for what he seems to be describing, and it

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lacks the descriptive style of the surrounding entries. Also, the entry didn't seem to correspond to any object that I knew of in the area. For me, this single line, "Group of eleven faint neb. VIIh 23m.4, N.33° 59'," began a search for the truth about what Webb saw.

"Eleven faint neb." I couldn't think of 11 nebulae in that region of Gemini. (The coordinates list the objects' position in 1920. The wobble of Earth's axis over the last 75 years changes the position slightly, by about 5 minutes in right ascension and by about -10' in declination.) I only had a few sources, *Burnham's Celestial Handbook, Sky Atlas 2000.0*, and the *Webb Society's Deep Sky Observer's Handbook*, available to check for any galaxy, star cluster, nebula, or combination of these that Webb could have seen as 11 nebulae near the reported position.

None of these sources lists any objects at this spot in the sky. The *Celestial Handbook* rarely includes objects below magnitude 13.5. The *Deep Sky Observer's Handbook* lists fainter objects, but it isn't complete at these magnitudes. So I reasoned that the mystery objects must be fainter than 13.5.

But if they are that faint, could Webb have seen them with any of his scopes? His large refractor probably enabled a glimpse of such faint objects. The 8- and 9-inch reflectors, newly silvered and with good optics, might have revealed objects slightly fainter, especially considering Webb's extraordinary observing skill. However, Webb observed many of the objects in his lists with his 3.7-inch refractor, which could barely reach 13th magnitude.

Although whether Webb observed the objects remained a mystery, the identity of the galaxies became somewhat clearer when I purchased *Uranometria 2000.0*. Chart 100 of volume one shows seven galaxies occupying this area of Gemini: NGC 2373, 2375, 2379, 2385, 2388, 2389, and 2393. Now I wondered why Webb's entry lists 11 galaxies and not seven.

M. Edouard Stephan of the Marseilles Observatory seems to be the one who contributed the observations that led to 11 entries in the *New General Catalogue* for this region (NGC 2373, 2375, 2378, 2379, 2385, 2386, 2388, 2389, 2390, 2391, and 2393). Not all of these objects are galaxies. According to California amateur Steve Gottlieb who observed the objects with a 13.1-inch reflector, NGC 2378 is a double star, NGC 2389 is a triple star, and NGC 2390 is a single

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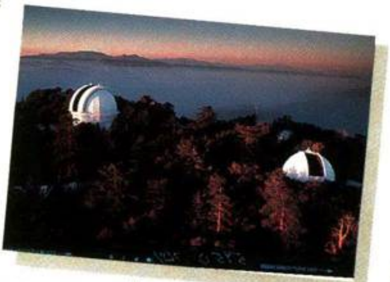

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star. Malcolm Thomson of New Mexico says that NGC 2378 and NGC 2379 are the same object.

According to Gottlieb, the seven galaxies range in magnitude from 12.8 to 15.2 (*NGC 2000.0* lists only photographic brightnesses for these galaxies). Webb could only have observed 11 objects if he made the same misidentifications as Stephan, and because they are so faint, it is doubtful that he could have observed all of them directly with his small scopes. Armed with this information, I concluded that odds are against Webb's having written the entry in Gemini.

To resolve the mystery of who wrote the entry, I asked the Webb Society for help. A group of British amateur astronomers formed this society in 1967 in order to encourage backyard astronomers to study deep-sky objects. (For more information, contact the North America chapter of the Webb Society, 1440 S. Marmora Ave., Tucson, AZ 85713-1015.) One of their activities is updating the information in *Celestial Objects*, publishing it in their *Deep Sky Observer's Handbook* series of volumes.

According to Alan Dowdell of the Webb Society, the mysterious entry did not exist in *Celestial Objects* from the first edition in 1859 through the fourth published in 1885 after Webb's death. The best guess is that the entry was added later by the Reverend T. E. Espin, who revised and reprinted Webb's book in 1893. Little is known about Espin except that Webb bequeathed him all his astronomical equipment.

Like Webb, it is doubtful that Espin directly observed these objects because he used Webb's scopes. He probably added the entry after learning of the objects in this area from the *New General Catalogue*, which was printed in 1888. After a long chase, Espin's hand as the source of the mystery at last reveals itself.

Celestial Objects for Common Telescopes will long be recognized for the classic it is, not only for the information it contains but for the wonderful personal touches that give us insight into Webb and his times. And over a hundred years later, it still seems to hold a mystery or two. □

Gordon Bond is a deep-sky observer living in Middlesex, New Jersey, and edits The Practical Observer, *the newsletter of the National Deep Sky Observer Society.*

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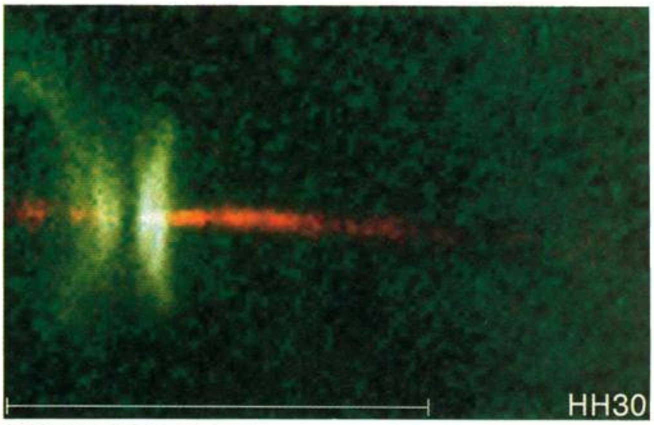
Hubble Observes the Violent Birth of Stars

The remarkable resolving power of the Hubble Space Telescope has provided astronomers with spectacular views of the immediate environment surrounding stellar birth. Before Hubble, astronomers knew that nascent suns were surrounded by dusty disks and that gaseous jets raced away from these protostars. But now astronomers, armed with Hubble, have followed these jets almost all the way into their host stars. They now know that these jets originate from the stars themselves, or just outside them, rather than from the outer parts of the disks as some theories had predicted. Hubble showed that jets become tightly focused just a few billion miles from their sources. No one yet knows exactly how the jets form or how they become so tightly collimated.

Hubble imaged bright clumps within the jets, called Herbig-Haro objects, and was able to measure their velocity (500,000 miles per hour). "The jet's clumpy structure is like a stockbroker's ticker tape. The clumps represent a recorded history of events that occurred close to the star," says Jon Morse of the Space Telescope Science Institute. "Like a putt-putt motor, variations every 20 or 30 years create the string of blobs we see."

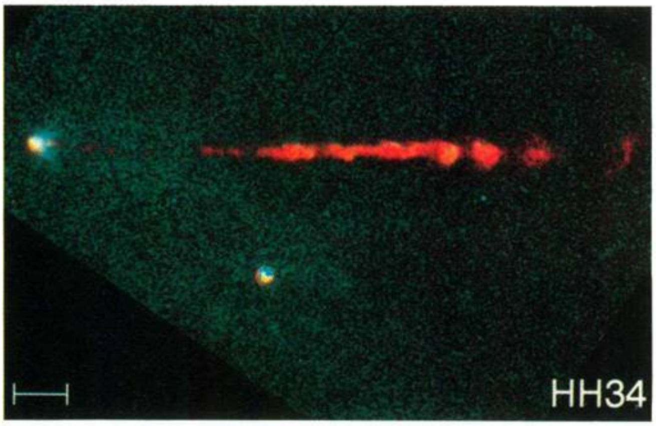
The new images also show that jets develop kinks along their multi-trillion-mile-long paths. One possible explanation is that the host star has a stellar or planetary companion whose gravity causes the star to wobble. The wobbling star acts like a shaking water hose, causing the jet to change course frequently.

The images were taken by Bo Reipurth of the European Southern Observatory, Christopher Burrows of the Space Telescope Science Institute, and Jeff Hester of Arizona State University in Tempe.



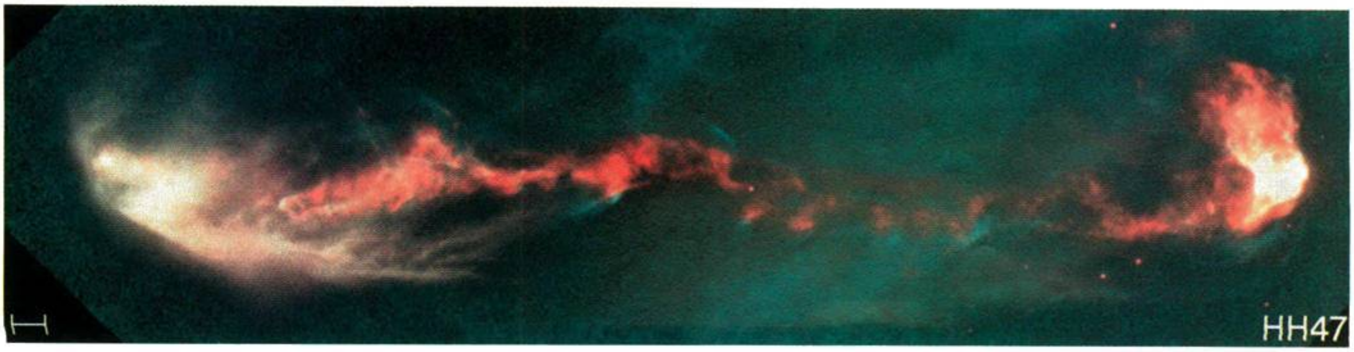
Christopher Burrows, STScI

A NEWBORN STAR illuminates a dusty disk while the star itself remains cloaked behind a dense band of dust. The jet originates from either the innermost region of the disk or from the star itself. The bar in the lower left for all three images represents 1,000 times the Earth-Sun distance.



Jeff Hester, Arizona State Univ.

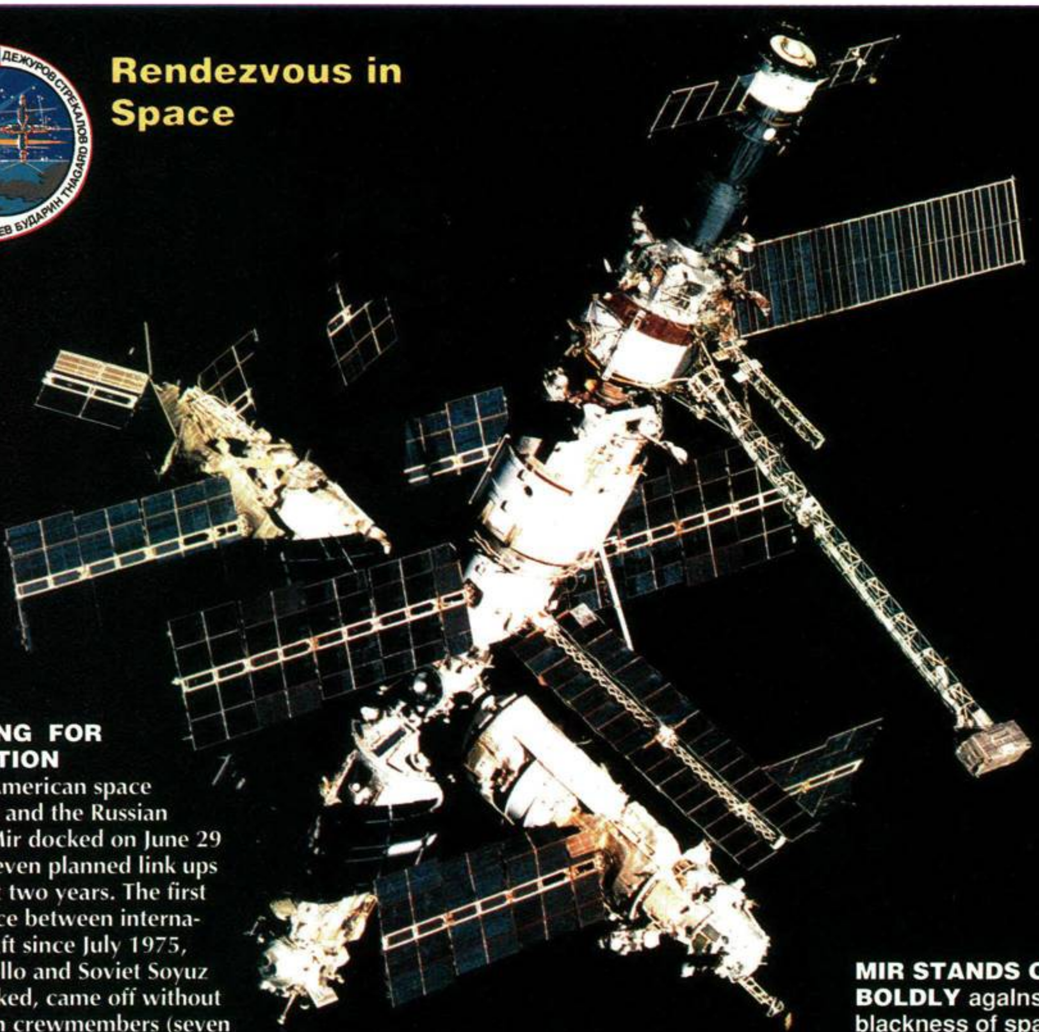
KNOTS CLOCKED AT 500,000 MPH race away from a protostar. The string of knots indicates that material is ejected from the protostar in a quasi-periodic manner rather than as a steady flow.



Jon Morse, STScI

A STELLAR COMPANION is indicated by the jet's wiggling pattern. The protostar is at the far left, hidden inside a dense cloud of gas and dust. The jet spans 3 trillion miles, or half a light-year.

Rendezvous in Space

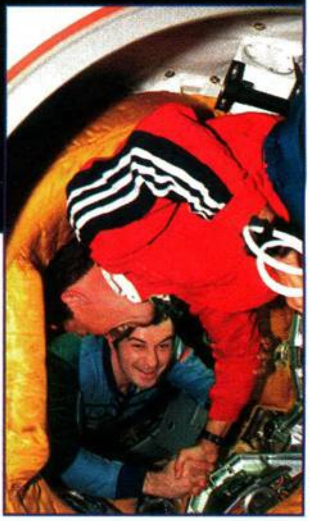


PREPARING FOR SPACE STATION ALPHA, the American space shuttle Atlantis and the Russian space station Mir docked on June 29 in the first of seven planned link ups during the next two years. The first meeting in space between international spacecraft since July 1975, when U.S. Apollo and Soviet Soyuz spacecraft docked, came off without a hitch. The ten crewmembers (seven on Atlantis and three on Mir) tested procedures that will be needed during construction of the international space station. That joint project among the United States, Russia, Canada, Europe, and Japan is set to begin in 1997.

MIR STANDS OUT BOLDLY against the blackness of space as the space shuttle Atlantis approaches prior to their historic docking.

ATLANTIS LIFTS OFF from launch pad 39A on the 69th space shuttle flight and the 100th manned U.S. flight.

CREWMEMBERS POSE for an inflight portrait. Clockwise from bottom, they are Greg Harbaugh, Hoot Gibson, Charlie Precourt, Nikolai Budarin, Ellen Baker, Bonnie Dunbar, Norm Thagard, Vladimir Dezhurov, Gennady Strekalov, and Anatoly Solovyev.



SHUTTLE COMMANDER Gibson greets Mir-18 commander Dezhurov in the tunnel joining the two ships.

NASA images

Sun's Future Not So Bright

The Sun, our planet's seemingly never-ending source of light and heat, may actually dim by the middle of the next century, cooling temperatures on Earth as much as 2° Fahrenheit. Astrophysicist Sallie Baliunas from the Harvard-Smithsonian Center for Astrophysics and colleagues announced this finding after examining starspots, regions of intense magnetic activity, on other stars.

Sunspots, which appear as dark patches on the Sun's disk, have long provided clues to magnetic and solar activity levels. Likewise, spots on other stars indicate the strength of its magnetic field. In addition, a star will brighten during times of increased activity and dim during times of decreased activity. Spots on the Sun wax and wane in roughly 11-year cycles, too short of a time to create any significant temperature changes on Earth. But the new starspot research points to more sustained cycles — on the scale of centuries.

Scientists obtained information about possible fluctuations in the Sun's magnetism by surveying about 800 stars located between 10 and 100 light-years away. "Together as a group, these stars are like time machines, because they help us understand the Sun's past, present, and future," says Baliunas.

The future doesn't look bright, though. The study suggests that our own Sun may decrease in brightness by about 0.4 percent within the next 50 years.

Supporting their finding is data gathered from 7,000-year-old bristlecone pines. By looking at the tree's rings, researchers can measure levels of C^{14}, a radioactive form a carbon. During times of low magnetic activity on the Sun, cosmic rays create more C^{14} in the upper atmosphere, which is eventually absorbed by the trees. "Combined with the star survey, this information suggests that the Sun's magnetic activity dwindles roughly one century out of every three," remarks Baliunas.

A two-degree decrease in global temperature every 300 years may not seem very dramatic. But consider a time between 1645 and 1715 when Europe's climate averaged about two degrees lower than it is today. Scientists now refer to this 70-year period as the Little Ice Age.

From Black Holes to Quarks

Physicists have gotten used to the idea that black holes can do some pretty bizarre things, such as emit radiation and explode.

Brace yourself for an even crazier idea. A team of theorists propose that mini-black holes, the type that formed shortly after the Big Bang, can actually turn into elementary subatomic particles. In this process, a black hole undergoes a phase transition, just as ice undergoes a phase transition when it melts into water. "If you were watching one of these black holes in your laboratory, you would initially see it as looking like a black hole, and later on you'd see it as a quark or an electron. It would be a spectacular thing to observe," says Cornell physicist Brian Greene, who derived this result along with University of California at Santa Barbara physicist Andrew Strominger and Duke mathematician David Morrison.

This work is a consequence of string theory, which postulates that all matter in the universe consists of virtually massless wisps of energy that are trillions of

AMATEUR NEWS

A Man's Dome is Not His Castle

Planetary observer Mark Thompson has lost his battle with neighbors and city hall, with implications to property rights and neighborliness that all astronomers should heed. The city of Seal Beach, California, has ordered that a dome Thompson installed to protect his Questar 3.5 must be removed from his house.

The story starts five years ago when Thompson got city approval to remodel his home. With a new baby on the way, Thompson and his wife Elizabeth received a permit to add a bedroom, a den, a roof deck with a staircase, and an observatory with a two-meter telescope dome. During the approval process, Seal Beach's planning commission signed off on the plans with no objections.

Soon after construction began, however, a next-door neighbor became concerned and claimed that the dome was not only an eyesore, but illegal as well. He and 300 others signed a petition that said citizens didn't like the appearance of most covered roof-access structures found on beach homes in the coastal city. The petition triggered a city council order to halt the observatory's construction and order a multi-year survey of all covered roof-access structures.

The study concluded that 100 of the 150 covered-roof access structures, including Thompson's dome, did not conform to code. This group had to go through height variance hearings in order to keep their add-ons. All but one, Thompson's observatory, were approved. When Thompson appealed to the planning commission, which had earlier ratified his plans, he was told the dome had to be removed because he had misrepresented his plans.

A plea before city council yielded a one-year extension, which finally ran out last December. Feeling that a legal battle was not worth the expense when combined with the heartache already endured, Thompson begrudgingly removed the dome earlier this year. A new conforming structure, sans dome, is under construction now.

The lesson from all this, Thompson says, is "that the public needs to be educated more about astronomy and how telescopes are used for looking up, not spying on neighbors." He mentions that since observatory domes are not a common sight, neighbors should know what's being built before construction begins. An observatory might not be accepted by everyone in the neighborhood. Finally, he says, design an observatory so the dome isn't eye-catching or distracting.

And what of the Thompson's dome? It will soon find a new home with its big brothers on Palomar Mountain and house a second telescope in the Telescopes in Education program. — *Stephen Edberg*

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9mm	1¼"	50°
10mm	1¼"	50°
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20mm	1¼"	50°
25mm	1¼"	50°
30mm	2"	50°

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VSP

Tripod - Alt-Az Photo Mount

TRIPOD – ALT-AZ PHOTO MOUNT. This tripod mount serves as a super heavy duty photo tripod for cameras with large telephoto lenses, spotting scopes or binoculars. This unit can also be used for small telescope owners who want to upgrade their mounts. It comes with two slow motion cables, adjustable wood tripod and with a ¼ x 20 photo head.

REDUCER/CORRECTOR f/6.3 – This combination focal reducer and field corrector lens accessory works with all Celestron SC's. Now it is possible to have a dual focal ratio instrument without sacrificing image quality. The Reducer/Corrector is f/6.3 for C5, C8, C9˘, and C11, f/7 for C14. The drawbacks of a dedicated f/6.3 Schmidt-Cassegrain with its much larger central obstruction (causing reduction of contrast) and the inability to utilize longer focal ratios for certain objects led us to design this four element, fully multi-coated accessory. Results are amazing BOTH visually and photographically. ***Far superior to competitive units!***

Reducer/Corrector f/6.3

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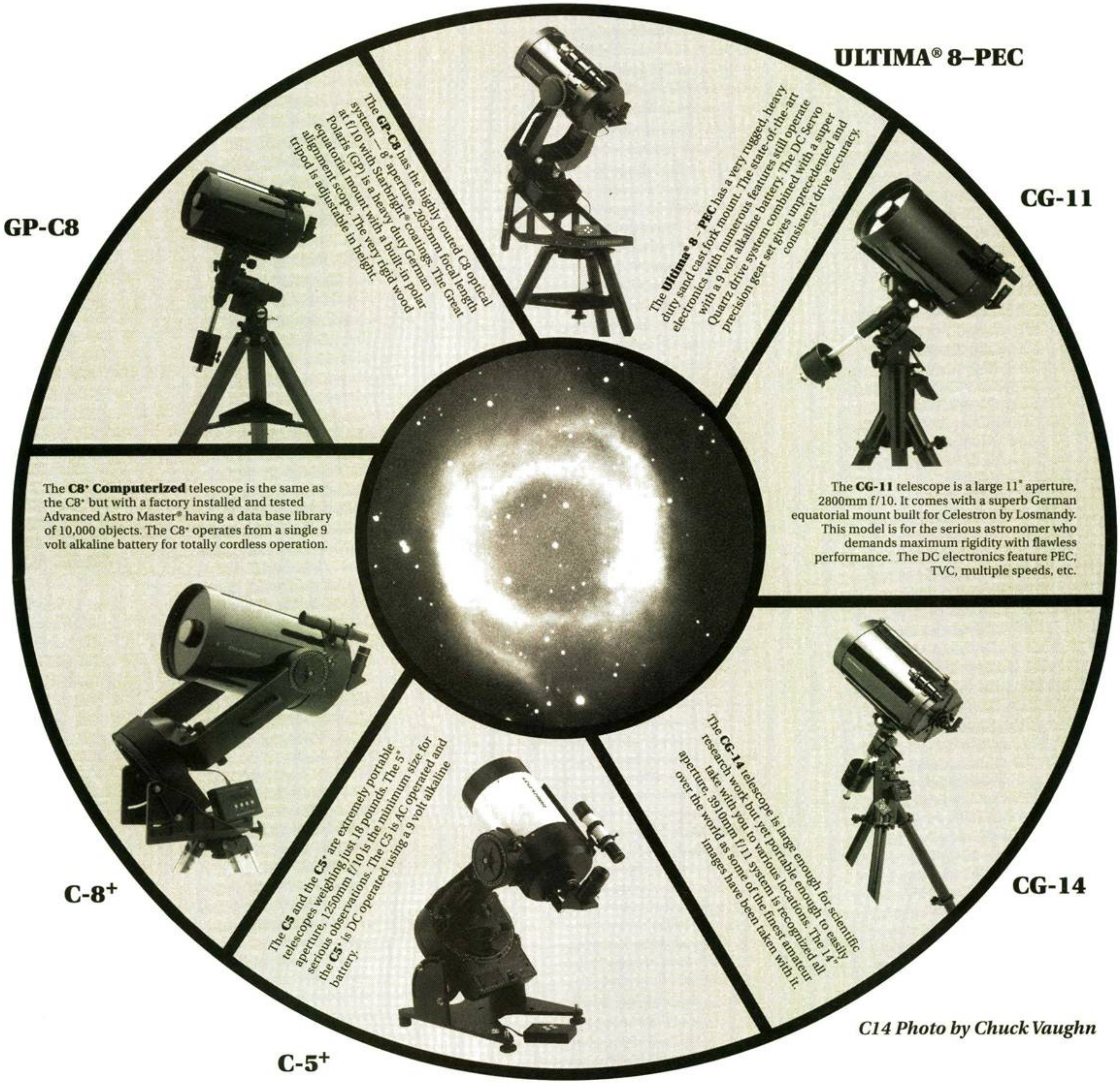

The **GP-C8** has the highly touted C8 optical system — 8" aperture, 2032mm focal length at f/10 with Starbright® coatings. The Great Polaris (GP) is a heavy duty German equatorial mount with a built-in polar alignment scope. The very rigid wood tripod is adjustable in height.

The **Ultima® 8 – PEC** has a very rugged, heavy duty sand cast fork mount. The state-of-the-art electronics with numerous features still operate with a 9 volt alkaline battery. The DC Servo Quartz drive system combined with a super precision gear set gives unprecedented and consistent drive accuracy.

The **C8$^+$ Computerized** telescope is the same as the C8$^+$ but with a factory installed and tested Advanced Astro Master® having a data base library of 10,000 objects. The C8$^+$ operates from a single 9 volt alkaline battery for totally cordless operation.

The **CG-11** telescope is a large 11" aperture, 2800mm f/10. It comes with a superb German equatorial mount built for Celestron by Losmandy. This model is for the serious astronomer who demands maximum rigidity with flawless performance. The DC electronics feature PEC, TVC, multiple speeds, etc.

The **C5** and the **C5$^+$** are extremely portable telescopes weighing just 18 pounds. The 5" aperture, 1250mm f/10 is the minimum size for serious observations. The C5 is AC operated and the **C5$^+$** is DC operated using a 9 volt alkaline battery.

The **CG-14** telescope is large enough for scientific research work but yet portable enough to easily take with you to various locations. The 14" aperture, 3910mm f/11 system is recognized all over the world as some of the finest amateur images have been taken with it.

C14 Photo by Chuck Vaughn

Celestron offers the discriminating buyer a variety of U.S.A. made Schmidt-Cassegrain telescopes to choose from to satisfy individual preferences in style, aperture and features. Purchasing a Celestron translates into pride of ownership and satisfaction of knowing you have obtained the ultimate in optical precision and mechanical execution. A Celestron telescope will become a complete entertainment center for you, your family and friends.

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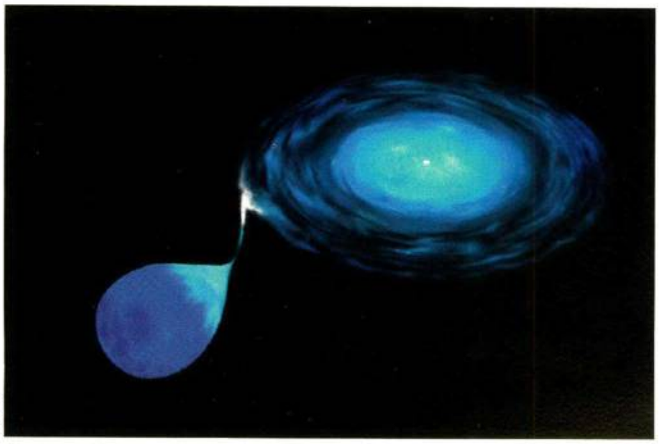
times smaller than an atom. Scientists do not yet have the technology required to test string theory in the laboratory, but many physicists believe it to be the ultimate theory of nature because it unifies all of modern physics into one all-encompassing and aesthetically beautiful framework.

Previously, black holes didn't fit into the theory since they could not be modeled as vibrating strings. But this new result represents a quantum leap forward for string theory because it shows that black holes and elementary particles at the subatomic level are two different descriptions of the same thing.

Hubble Views Stellar Fireworks

At the heart of VW Hydri, an exploding star system called a cataclysmic variable, lies the burned out core of a star, a white dwarf. Gas from its normal, companion star flows onto the white dwarf, releasing an immense burst of energy. This burst heats the white dwarf's surface, but recent Hubble Space Telescope observations show the heating isn't as much as theorists had predicted. The surface temperature is only about 20,000 kelvins compared to 100,000K predicted by theory. For the first time, Hubble permitted observers to directly view the white dwarf without obscuration by the companion's gas.

The team of astronomers, led by Edward Sion of Villanova University in Villanova, Pennsylvania, also found that the white dwarf rotates five times more slowly than first suspected. Despite several million years of accumulating gas that should make the star spin faster, the star apparently has an efficient but unknown method of losing rotational energy. The team reported their observations made with Hubble's Faint Object Spectrograph and Goddard High Resolution Spectrograph in the May 10 and May 20 issues of the *Astrophysical Journal Letters.*

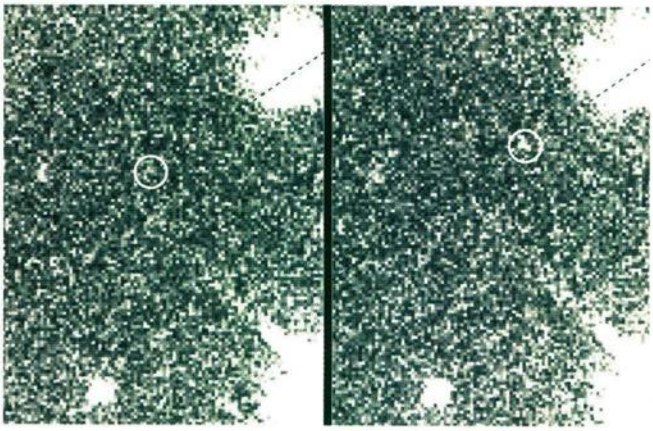


STScI

CRASHING INTO THE SURFACE of a white dwarf star, gas from a normal companion heats up the surface of the white dwarf and causes it to emit a burst of energy.

First Drops in a Comet Reservoir

Thanks to the Hubble Space Telescope, astronomers have finally proven that short-period comets come from a vast region of space beyond Neptune. This is the realm of the Kuiper disk — an enormous population of shadowy mini-ice worlds that slowly orbit the Sun in near total darkness. Astronomers think the Kuiper disk is the fossilized remnant of the dusty disk from which the planets formed (see "Chiron: Interloper From the Kuiper Disk?" August 1994).



A. Cochran, University of Texas and NASA

ONE IN TEN BILLION, a putative Kuiper disk comet slowly creeps across the sky in these two 5-hour Hubble Space Telescope exposures taken 1¾ hours apart. The dashed line traces the object's orbit. The comet's diameter is roughly 10 kilometers.

Since the 1950s astronomers have suspected the existence of a vast reservoir of short-period comets. The Kuiper disk was the prime candidate. To test this idea, Anita Cochran of the University of Texas at Austin, Harold Levison and Alan Stern of the Southwest Research Institute in Boulder, Colorado, and Martin Duncan of Queen's University in Kingston, Ontario, used Hubble's Wide Field Planetary Camera 2 to take a series of deep images of a relatively empty patch of sky in Taurus. The team used sophisticated image processing and statistical techniques to eliminate unwanted stars, galaxies, and cosmic ray strikes on Hubble's CCD detectors. What they had left were about 30 objects with motions consistent with objects beyond Neptune.

At the time the Hubble team announced their discovery in June 1995, ground-based telescopes had already discovered 27 Kuiper disk objects. All 27 were at least 100 kilometers in diameter — much larger than the comets that penetrate the inner solar system. The newly discovered objects, however, are estimated to be between 6 and 12 kilometers in diameter, which is the same size as comets like Halley, Encke, and West. "For the first time we can point to a specific region of the solar system and say, 'That's where short-period comets come from,'" says Cochran. Astronomers think that as many as 10 billion of these small ice worlds populate the outer solar system between 30 and 50 AU.

In a related paper, Stern has simulated the collisional evolution of the Kuiper disk, and has reached a startling conclusion. He plugged the present-day population and orbits of Kuiper disk objects into a computer model and then watched the bodies crash into one another. The bodies stuck together to form larger objects. But Stern found that the largest bodies, which are full-fledged mini-planets 400 kilometers across, would take 50 times the age of the solar system to form.

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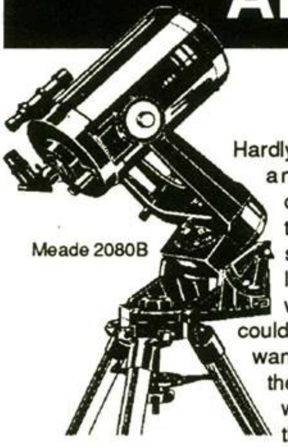

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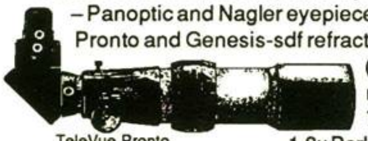

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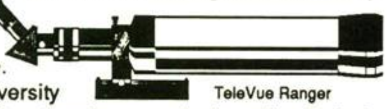
At ***astronomics***, we keep virtually the entire TeleVue line in stock – Panoptic and Nagler eyepieces; Barlows; camera adapters; Pronto and Genesis-sdf refractors; the Genesis-sdf Sky Tour (with computer, oak Gibraltar mount, Starbeam finder, a *free* 7mm Nagler eyepiece, a *free* 1.8x Barlow, observing chair, and more!)



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objects in the present-day disk unless you have tens of billion of years. There's just not enough stuff out there," says Stern. "What that indicates is that the disk has evolved drastically since the early days. The disk we see today is probably the thin remnant of a formerly much more massive disk."

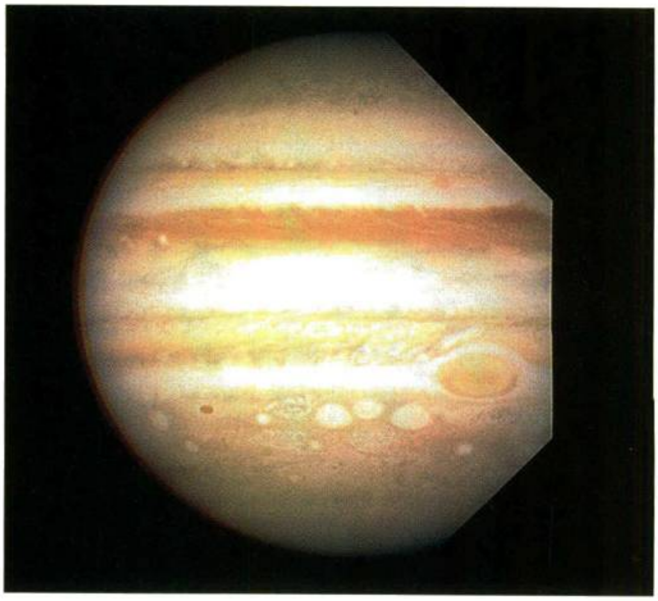
Stern says the solar system's early disk may have been similar to the thick, dusty disks astronomers have observed around newborn stars such as Beta Pictoris. With more material available during the early stages of planet formation, Kuiper disk objects grew faster and some were thus able to attain mini-planet status. Within a few million years the Sun went through an exceptionally windy stage and swept most of the remaining dust out of the disk into the Galaxy, leaving behind the comets and mini-planets we see today. "The early Kuiper disk was much more massive, and it would have been a mind-boggling structure from the surface of Earth if you could have seen it," says Stern.

Galileo and Hubble Prep for Jupiter Encounter

A thruster firing last April 12 has put the Galileo spacecraft in line for an encounter with Jupiter this December. A total of 64 tiny puffs from the spacecraft's thrusters changed the craft's trajectory by a mere 8 centimeters per second, or about 0.2 kph. This final adjustment came in preparation for the release of Galileo's 339-kilogram atmospheric probe on July 13.

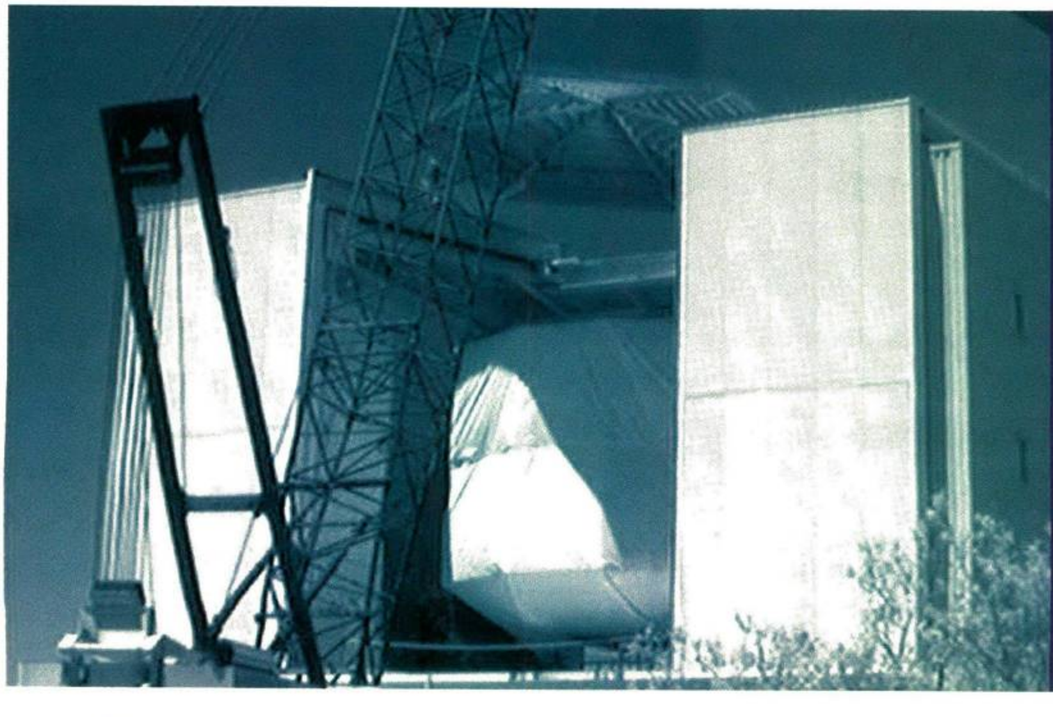
The probe, shaped like a flat cone and chock full of instruments that sample gases, careens into Jupiter's atmosphere on December 7 at 5:04 p.m. EST. At that time, Galileo will relay radio signals from the parachute-borne probe as it sinks 640 kilometers into Jupiter's clouds for the next 75 minutes. Once the probe goes silent, Galileo's orbiter will fire its main engine for nearly an hour to go into orbit and begin a two-year study of Jupiter and its family of 16 moons.

To help mission planners select interesting targets, astronomers are using the Hubble Space Telescope to conduct photo surveys of Jupiter's clouds. Among other things, teams have been monitoring three white ovals near the Great Red Spot. For the rest of Galileo's mission, HST will provide a global view of Jupiter while Galileo snaps close-ups. ☐



STScI

HUBBLE HELPS GALILEO READY for its encounter with Jupiter on December 7. Any interesting features, such as the white ovals near the Great Red Spot, will be targeted by mission planners for scrutiny by Galileo during its two-year mission.



MMT/SAO and U. Arizona

TO HOLD A NEW GIANT MIRROR, engineers renovated the Multiple Mirror Telescope located on Mount Hopkins, south of Tucson, Arizona. From last May to August, they extended the dome doors to accommodate the new 6.5-meter mirror and added shutters on the rear of the building to improve air flow and, thus, seeing. Converting the scope from its present six mirrors to one will occur in mid-1996 with first light through the "new" scope expected in early 1997.

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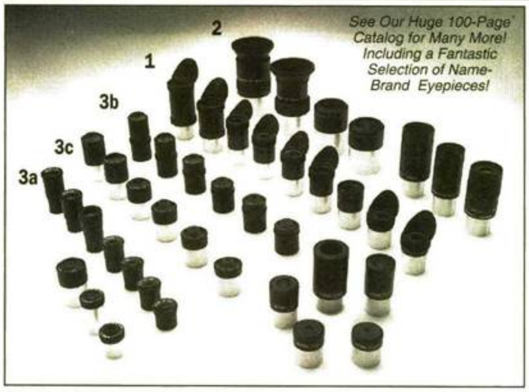

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SC UltraBlock Filter fits rear cell of Meade & Celestron SC scopes. #5656 ***$149 ea.*** (3.67)

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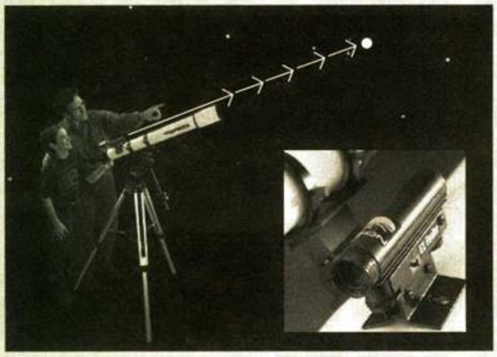

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6x30mm-Same unit used on $1000+ "big name" telescopes. With 2-ring metal bracket, fits scopes 6"-12".
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$49.95 (3.41)

6x30mm Right Angle-90° prism for right-angle viewing. Includes bracket.
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8x50mm Illuminated Wireless illuminator with adjustable brightness. #7092 (white) #7096 (black) ***$119*** (3.41)

9x60mm 44% more light grasp than 50mm models. #7091 (white) #7095 (black) ***$119*** (3.41)

9x60mm Illuminated Wireless illuminator with adjustable brightness.
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Threads to rear cell of telescope, requires t-ring for your camera model.

for SC	#5116 ***$26.95*** (2.98)
for C-90	#7115 ***$34.95*** (2.98)

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#7033 ***$36.50*** (2.19)

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For Schmidt-Cass. #8771 ***$219*** (4.71)

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Complete system requires Sky Wizard Model 1, 2 or 3 and a telescope installation package, sold separately

Installation Packages

Includes 2 encoders, all required mounting hardware and brackets, connecting cables, and complete illustrated instructions.
Installation packages are available for most telescope models. Call for details.

starting at $177

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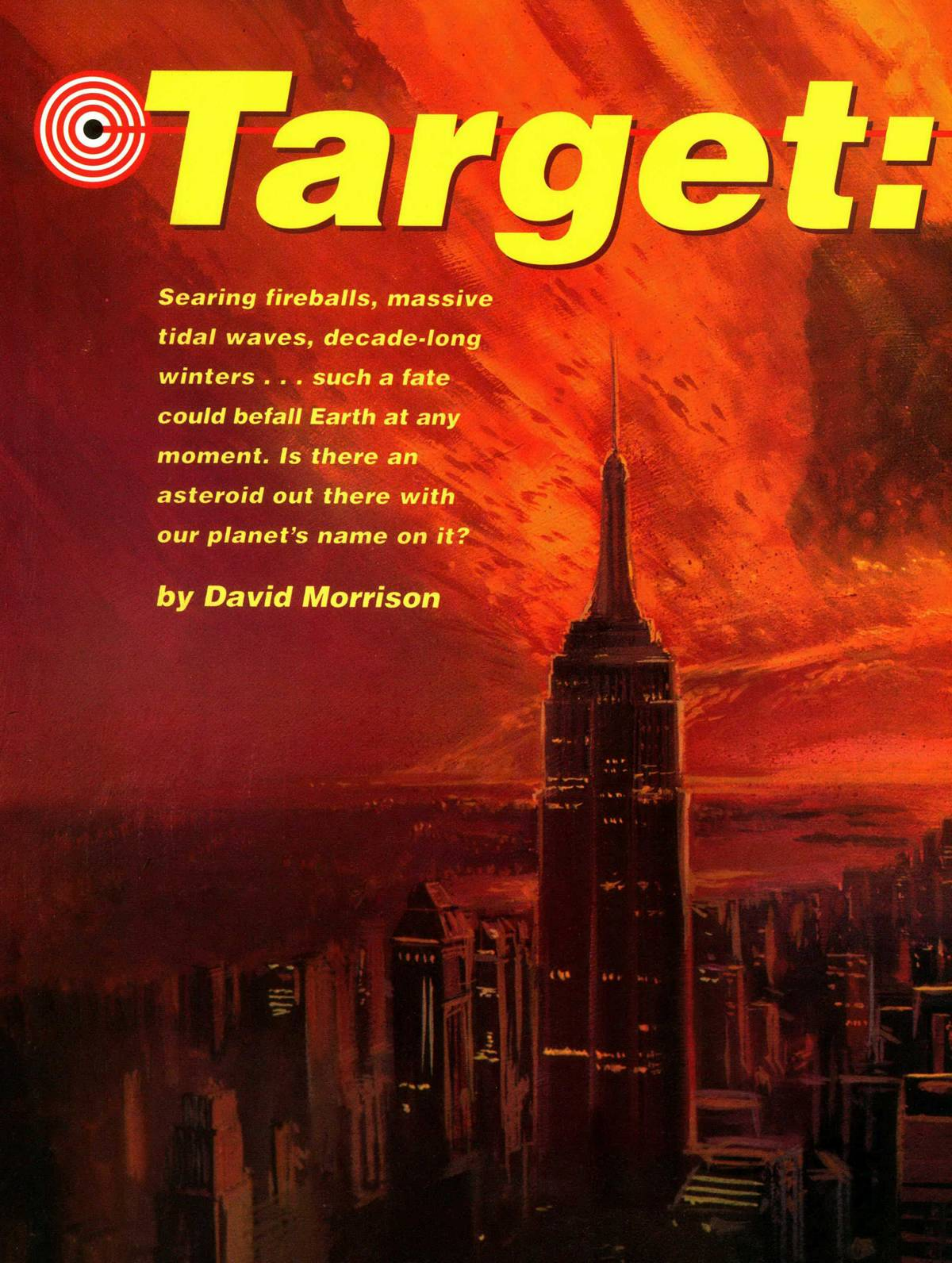
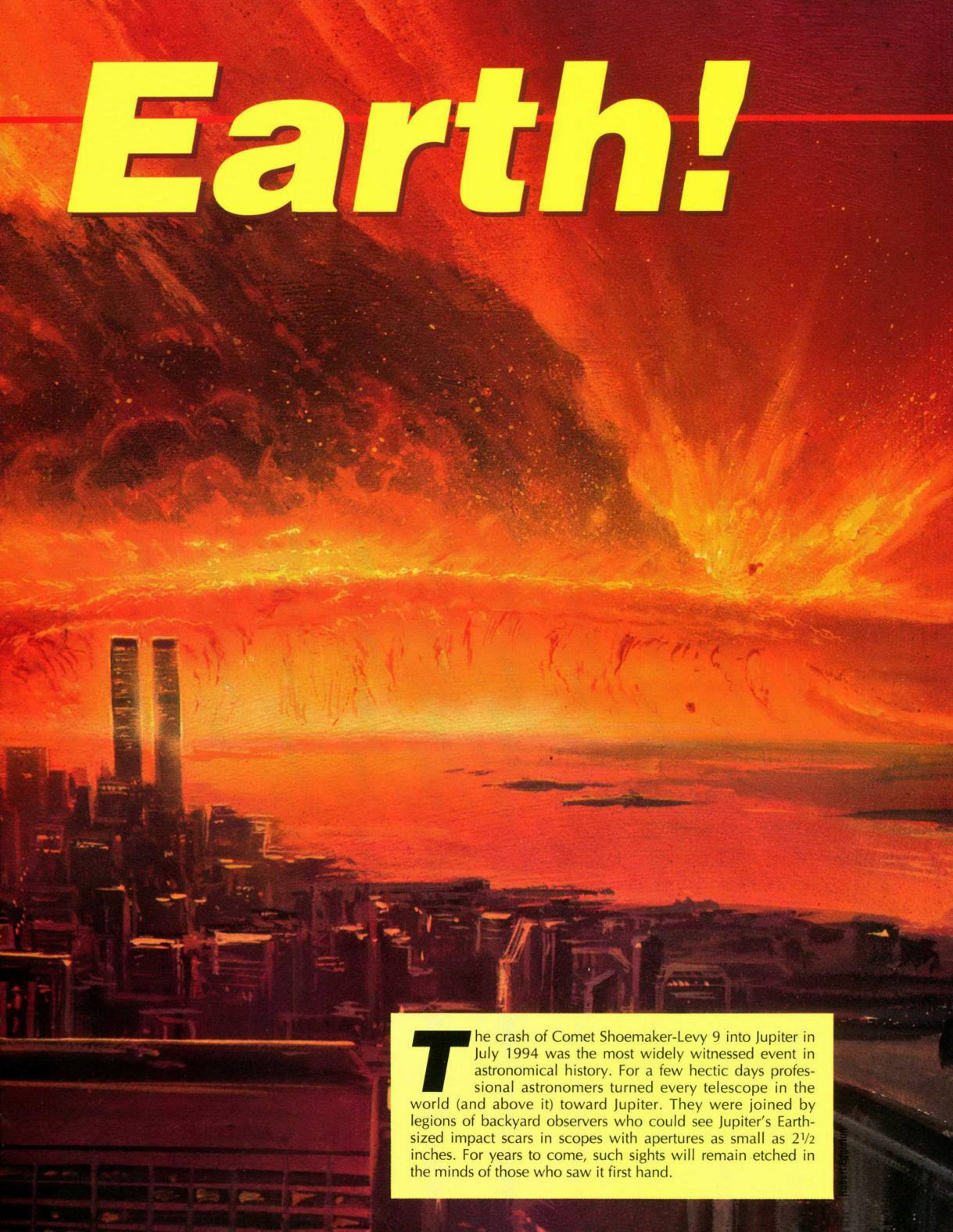
Target:

Searing fireballs, massive tidal waves, decade-long winters . . . such a fate could befall Earth at any moment. Is there an asteroid out there with our planet's name on it?

by David Morrison



Earth!



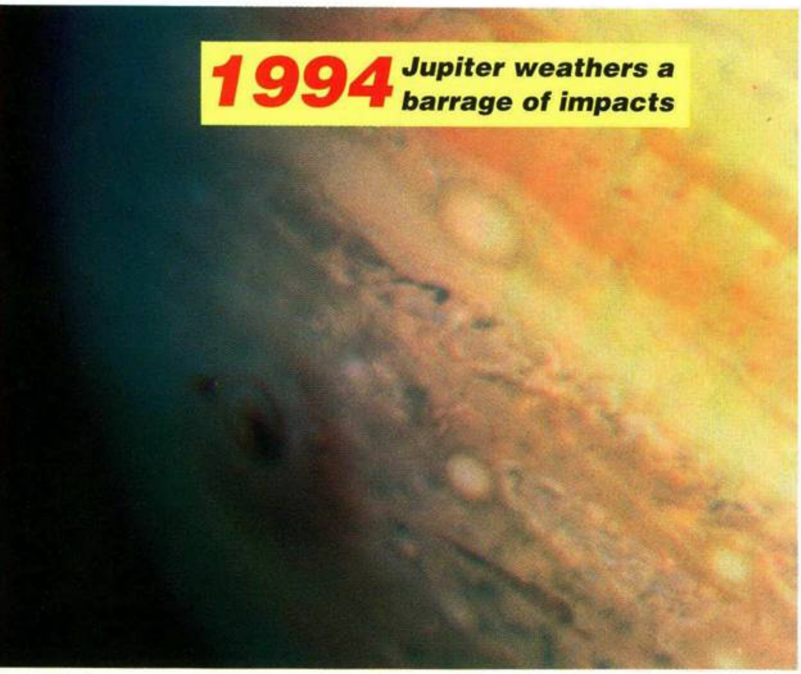
Robert Eggleton

The crash of Comet Shoemaker-Levy 9 into Jupiter in July 1994 was the most widely witnessed event in astronomical history. For a few hectic days professional astronomers turned every telescope in the world (and above it) toward Jupiter. They were joined by legions of backyard observers who could see Jupiter's Earth-sized impact scars in scopes with apertures as small as 2½ inches. For years to come, such sights will remain etched in the minds of those who saw it first hand.

Target: Earth!

This indelible legacy of the Great Comet Crash of 1994 raised humanity's awareness of catastrophic impacts in the solar system. Watching Jupiter suffer hit after hit left scientists and laymen wondering aloud if the same thing could happen to Earth.

Truth is, planetary scientists have known for a long time that Earth is subject to bombardment from space. You have only to look at the Moon's battered landscape to realize that we live in a bad neighborhood. Cosmically speaking, Earth and Moon are very close neighbors, and whatever rain of debris hit our satellite must have had a similar effect on Earth. Were it not for the constant reworking of Earth's surface by erosion and plate tectonics, our planet would be as densely cratered as the Moon.



1994 **Jupiter weathers a barrage of impacts**

NASA/STScI

The real scientific question is not whether Earth has been battered by impacts over its long geological history. We know that for a fact. What's revolutionary in today's thinking is that our fragile environment can be disrupted by relatively small impacts. And it's not just the immediate effects of an impact we should be concerned with; S-L 9 has helped us get a feel for consequences that *can linger long* after the initial strike.

All this is a far cry from barely 20 years ago, when few scientists even considered the possibility that asteroid hits could shuffle Earth's biological deck.

Survival of the Toughest

Our thinking about how asteroid impacts influence Earth's environment began to change with a serendipitous discovery in 1978. Lius and Walter Alvarez of the University of California at Berkeley were searching geological rock layers for a largely extraterrestrial element called iridium. Iridium, they figured, drizzled down on Earth at a nice, steady rate in the form of meteor dust. Measuring the amount of iridium in these layers could help scientists figure out how fast sediments collected on the floors of ancient oceans.

What they found instead was a major infusion of the element in a rock boundary between the Cretaceous and Tertiary eras, which marks when the age of dinosaurs ended some 65 million years ago. There was enough iridium in the K/T boundary, they calculated, to equal a 10-kilometer-diameter asteroid.

Based on this evidence, the team announced that a 10-km asteroid, a Great Extinctor, caused an environmental catastrophe that ended the Cretaceous era. They concluded that the dinosaurs suffered a global cool-down caused by dust thrown up into the stratosphere by the impact. Today we now know that this dust cloud is just one of several environmental catastrophes associated with an impact of this size.

As if this astounding discovery weren't enough, the Alvarezes went on to propose a sweeping generalization. If a hit of this magnitude killed the dinosaurs, perhaps similar impacts might have happened at other times in Earth's history and played a major — perhaps dominant — role in biological evolution. With asteroid impacts in the picture, suddenly one of a species' most important traits is its ability to survive random cosmic assaults. The winner of an evolutionary race is not a species that is stronger or faster or even smarter, but one that survives an occasional intruding asteroid or two. Natural selection still works, but the context has changed. Asteroids enter the evolutionary game as wild cards.

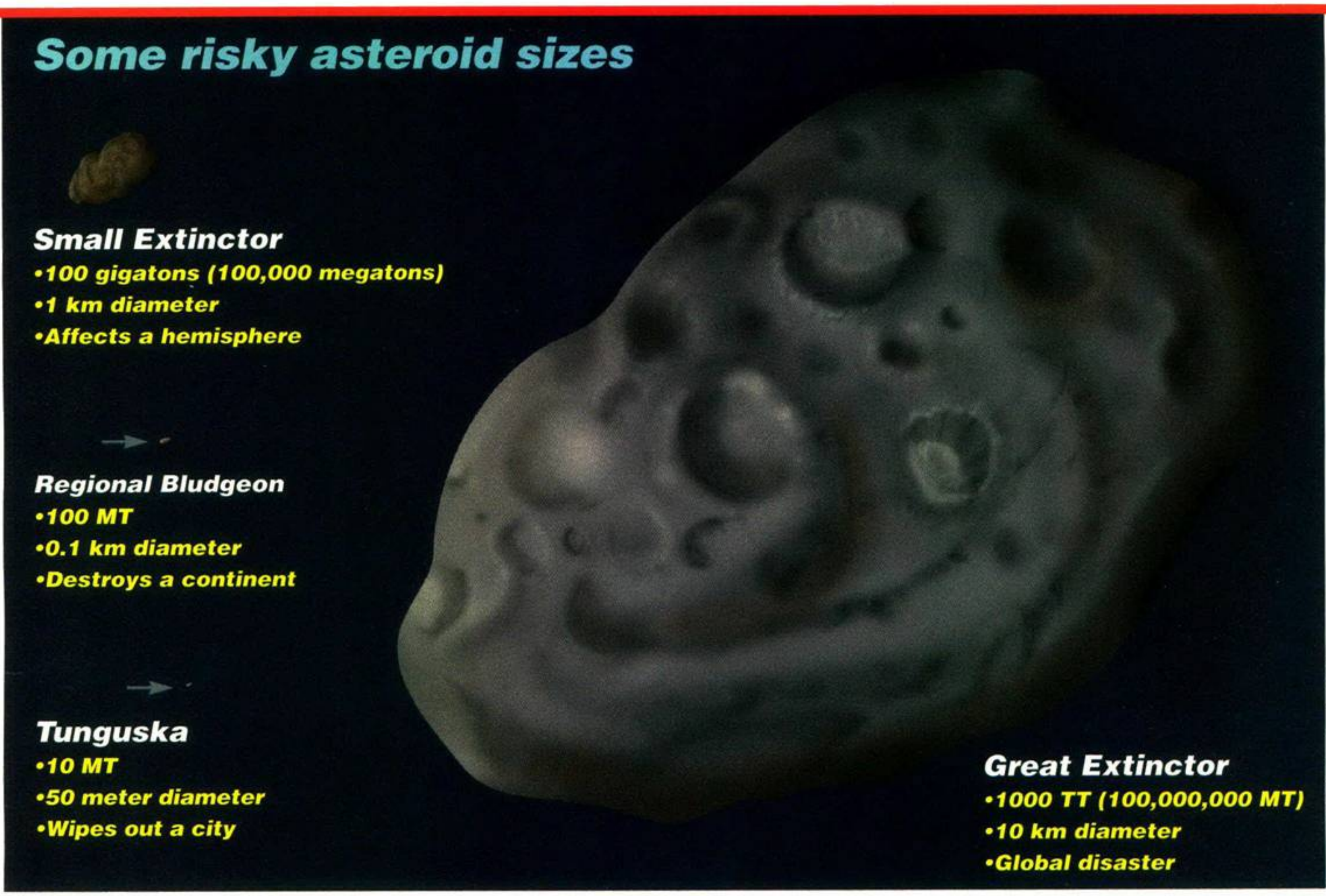
Over the past 15 years, evidence for a dinosaur-snuffing catastrophe has continued to accumulate, culminating with the 1991 discovery of a telltale crater (named Chicxulub) under Mexico's Yucatan peninsula. Scientists now estimate from the crater's size that the progenitor asteroid hit with an astounding energy equivalent to more than five billion Hiroshima atomic bombs (100 million megatons).

With that sobering statistic in mind, today geologists sift the geological record for hidden evidence that Earth might have suffered other impact-induced mass extinctions. Although that evidence is slow in coming, the events that killed the dinosaurs 65 *million years* ago are no longer a matter of serious dispute.

Skies of Fire, Tracts of Ice

Aside from the immediate effects of heat and concussion, two major post-impact events did the dinosaurs in: a firestorm followed by excessive cold. What we saw on Jupiter during Shoemaker-Levy's 1994 impact was a window to this lethal combination of fire and ice.

After fragments of Comet S-L 9 exploded in Jupiter's atmosphere they produced huge fireballs of hot gas and dust that rose high above the planet's clouds.



ASTRONOMY: Phil Kirchmeier after LLNL

Because Jupiter's atmosphere was literally blown away from above the impact site, hot gas and dust were funneled up to altitudes of 3,500 km. But in Jupiter's strong gravity, whatever went up had to come down. So for about 20 minutes after each impact, the dust-laden plumes fell back into the atmosphere, reentering with a *horrendous* release of energy. The heat from this reentry was so intense it was easily detected from Earth.

The same thing happened on Earth 65-million years earlier with the Chicxulub impact. But in our case, the plume included large quantities of rock and dust blown out from the crater. When this ejecta rained down about 30 minutes after the impact, it produced a meteor shower of almost unbelievable proportions. Meteors turned the sky red-hot and ignited terrestrial forests and grasslands. Telltale soot from this firestorm is found in sediments from the K/T boundary at sites all over the world. Most land animals probably perished by fire.

Then came the cold.

On Jupiter, large, black dust clouds remained clearly visible at each impact site for weeks, suspended in the stratosphere. Even more than a year after the impacts, not all the dust has settled back into the deep atmosphere. These bruises have substantially reduced the amount of sunlight that reaches Jupiter's lower cloudtops.

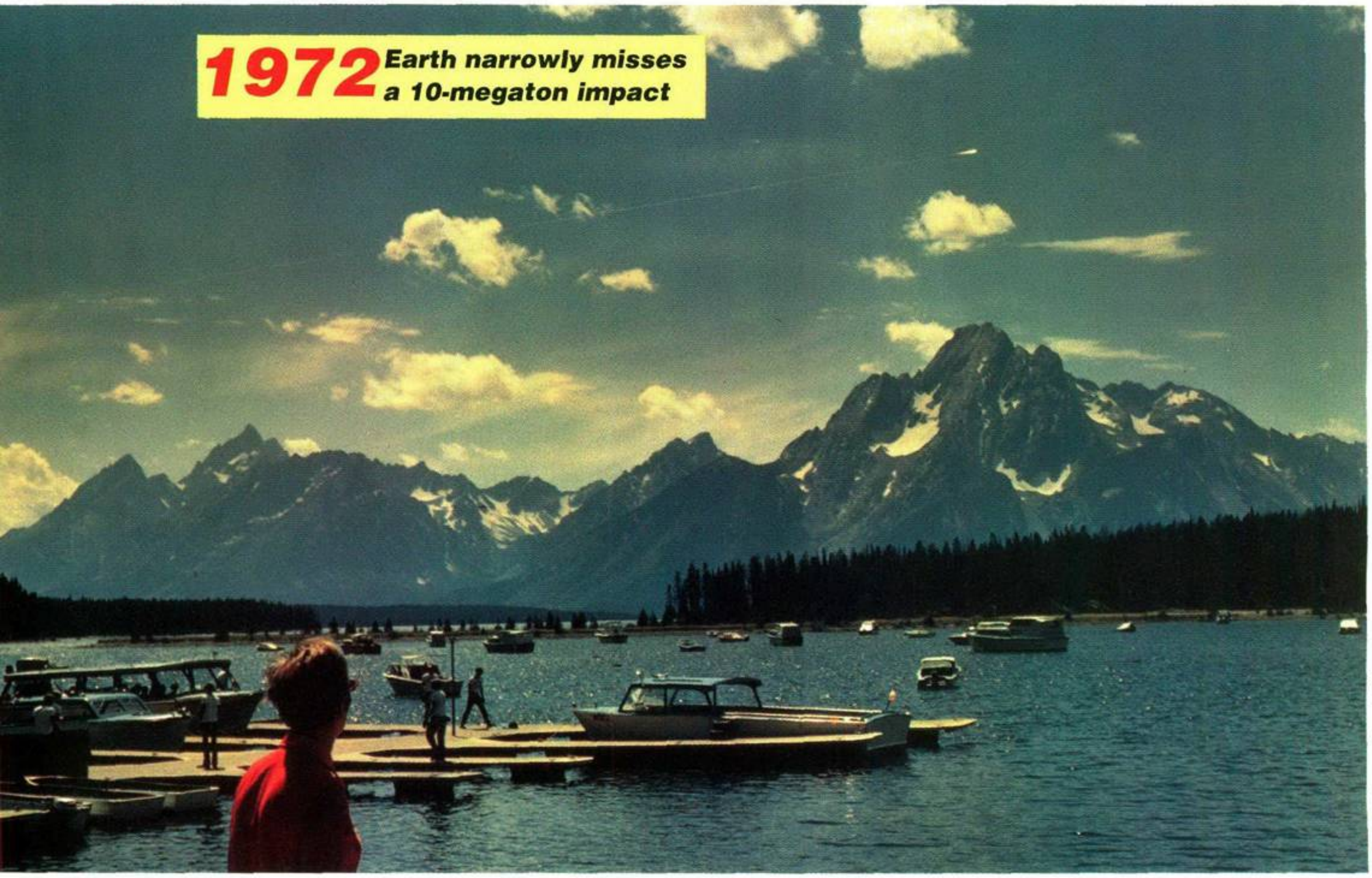
In Earth's case, the Great Extinctor hit in shallow water and excavated several times its mass in finely fractured target rock. Indeed, the total amount of material measured in the worldwide K/T boundary layer is about a hundred times greater than the mass of the 10-km asteroid that actually hit. Most of the layer has large grains that were blown horizontally by the impact and plume particles that were heated during atmospheric reentry. But a sizable portion of the layer is in the form of fine dust that remained suspended in the atmosphere for months, blocking photosynthesis and plummeting temperatures on the dark surface beneath the clouds.

Suppression of photosynthesis lead to a breakdown in the ocean food chain that killed most marine creatures. Survivors had to hunker down to a global drop in temperature not unlike the "nuclear winter" scenario postulated during the later days of the Cold War.

Still other environmental catastrophes drove the K/T mass extinction 65 million years ago, including global acid rain and destruction of the ozone layer. Species that survived one stress may have succumbed to another. But it was the thermal pulse from re-entering ejecta and the subsequent darkness caused by suspended stratospheric dust that did most of the killing.

Death by the Megaton

It's hard to imagine that all this carnage came from a relatively small asteroid no more than 10 km wide. But



1972 Earth narrowly misses a 10-megaton impact

James M. Baker and Dennis Milon

what the Great Extinctor lacked in size, it made up for in kinetic energy, measured in units the same way we measure the yield of thermonuclear weapons.

The energy of the Chicxulub impact was about 100 million megatons — that is, about five billion times the size of the atom bomb dropped on Hiroshima 50 years ago. Fortunately, events like Chicxulub are quite rare, occurring at intervals of 100 million years or more. But what about smaller impacts? Could these produce similar environmental effects?

Brian Toon and Kevin Zahnle at the NASA Ames Research Center have calculated the effects of smaller impacts. According to their work, a 3-km impactor, only 2% the mass of a Great Extinctor, would kick up enough dust to block photosynthesis. And given what we know about the number of small, near-Earth objects, such small hits are statistically possible during our lifetimes.

The Earth accumulates about 100 tons of extraterrestrial material every day under a constant rain of interplanetary debris. Most meteoroids enter the atmosphere and burn up unnoticed. Some survive the fiery heat of entry and are slowed down by air friction to a speed of about 320 km per hour. What's left hits the ground as a meteorite.

Big Ones Dig Deep

It's quite a different story when Earth's atmosphere can't slow down large meteoroids. Striking at their space velocity of 15 to 20 km/s, they explode on impact with an energy 100 times their mass in TNT. Since such an event would be much more destructive than a simple meteorite fall, it's natural to wonder what size meteoroid could devastate the Earth's surface.

Calculations by Christopher Chyba and Kevin Zahnle show that large objects entering Earth's atmosphere undergo tremendous stress due to air resistance. As the object fragments and covers more area along its line of travel, it creates more atmospheric resistance. Soon this process leads to a catastrophic break-up that causes the asteroid to decelerate explosively.

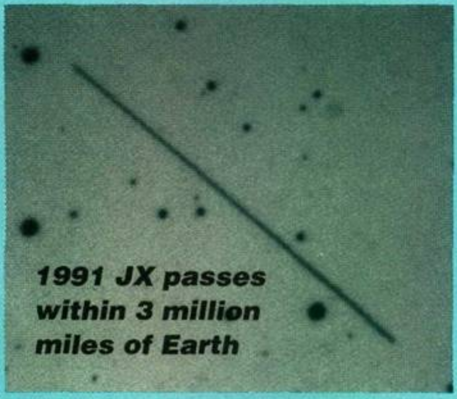
If such an explosion takes place at altitudes above 15 km, there is little harm done near Earth's surface. The outcome isn't so rosy if a larger object digs deeper into our atmosphere.

Ordinary stony asteroids, which have a rather crumbly composition, must be larger than 50 meters across (half the size of a football field) to do any damage at the ground. Such a projectile packs about 10 megatons of energy, comparable to the largest nuclear bomb.

They Stand On Guard for Thee

Sadly, more people work a typical shift at one fast-food restaurant than scan the skies for near-Earth asteroids. But what the searchers lack in numbers, they make up for in determination. Here's a brief listing of some searches underway or being planned:

- The California Institute of Technology's Palomar Planet-Crossing Asteroid Survey (PCAS) has been photographing the sky with an 18½-inch Schmidt telescope from Palomar Mountain in California since 1972. Films are carefully scrutinized under a stereo microscope for any objects that have moved between exposures. Program track record: 45 near-Earth objects, as well as 14 comets and several thousand main-belt asteroids.
- Another project associated with Cal Tech, the Palomar Asteroid and Comet Survey (PACS), runs in a similar fashion to the PCAS, but involves the resources of Arizona's Lowell observatory for follow-up observations. Since 1983, PACS has used Palomar's 18½-inch Schmidt telescope to discover 43 NEOs, plus now-famous comet Shoemaker-Levy 9, which collided with Jupiter in 1994. At press time, this search program is being phased out.
- The University of Arizona's Spacewatch survey is an all-CCD camera operation, using a rather sizable chip of 5 cm by 5 cm that covers a 38' field of view through a 36½-inch telescope on Kitt Peak. Astronomers turn off the telescope's clock drive and allow the sky to trail through a 2½-minute exposure. The final image shows stars as parallel streaks. NEOs appear as sideways streaks about 26 pixels long. The program's track record since 1981: An average of three NEOs each month — the smallest they've found is only 6 meters across.
- The Anglo-Australian Near-Earth Asteroid Survey (AANEAS) uses photographic plates taken through the 1.2-m U.K. Schmidt telescope operated at the Anglo-Australian Observatory in Siding Spring, Australia. Exposures are usually done for reasons other than an asteroid search; AANEAS merely tags along, looking for tiny but telltale streaks that betray the presence of an asteroid. The longer the streak, the closer the object is to Earth and the likelihood of it being an NEO. Up to 250 NEOs may lurk on plates yet to be scanned.
- The Lowell Observatory's Near-Earth Object Survey (LONEOS) is poised to come on-line near Flagstaff, Arizona. It uses a four-chip CCD camera mounted to a 16-inch Schmidt camera at Lowell.
- A larger survey effort called Spaceguard might use LONEOS's prototype CCD technology. First proposed in 1992, Spaceguard will station six 2.5-m survey scopes at strategic locations on Earth to cover the whole sky.



1991 JX passes within 3 million miles of Earth

Malcom Harvey/Duncan Steel, AATB

Thus, Earth's atmosphere protects us from smaller impacts, but not from those with 10 megatons or more energy. We can expect a 10-megaton impact about once per century on average.

To find one of the largest atmospheric explosions in recorded history, we need not look to hieroglyphs or deduce hidden imagery in ancient mythology. Earth reeled under a tremendous assault as recently as 87 years ago with the great Tunguska bolide of 1908.

On June 30 of that year, a 15-megaton explosion took place in the atmosphere above a desolate region of central Siberia, devastating more than 2,000 square km of forest. The Tunguska region is so remote, it wasn't until 17 years after the explosion that a scientific expedition visited the site. When the team arrived, they found no craters or evidence of the meteoritic fragments.

Many astronomy textbooks will tell you that the Tunguska impactor was probably a comet. If the Tunguska impactor had been cometary, however, it would have exploded at a higher altitude and done no damage. Had it been composed of denser iron, it would have reached the ground and made a crater. Meteor Crater in Arizona was formed by just such a metallic meteorite, with the same 15-megaton energy as Tunguska.

We now recognize the culprit as a rocky asteroid about the size of a city office building that decelerated and exploded at an altitude of 8 km. Last year, scientists apparently even found tiny fragments of this rocky object imbedded in tree resin at the impact site.

Playing Chicken With Oblivion

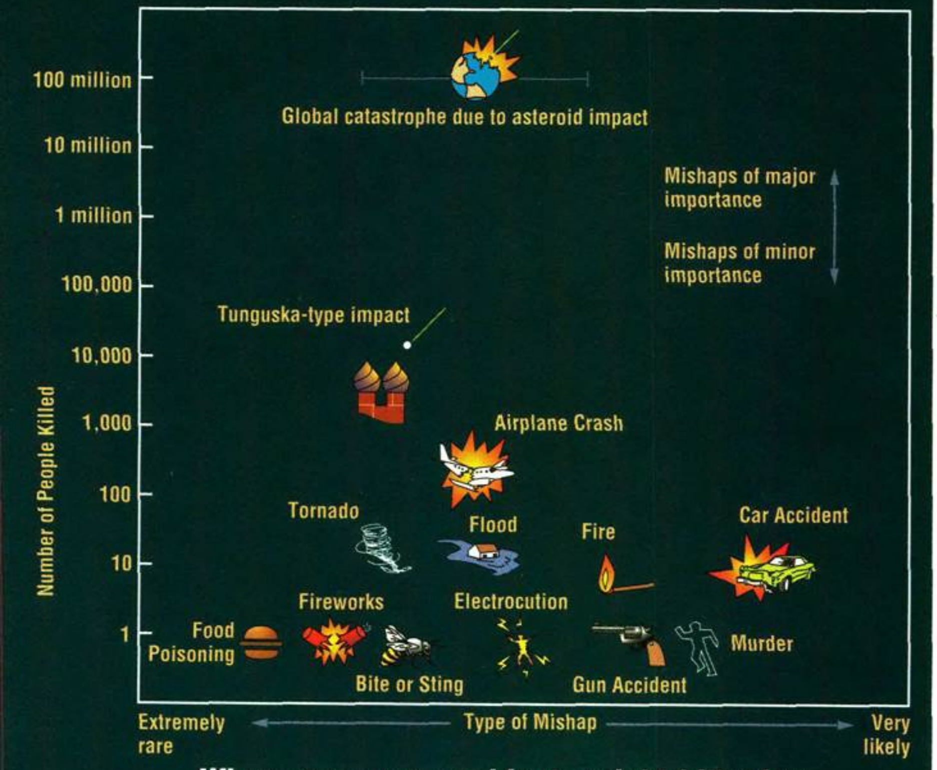
If "ground zero" for Tunguska (or Meteor Crater for that matter) had been a city, the destruction would have been terrible — equivalent to that of a large nuclear bomb. Such impacts happen about once every 300 years anywhere on Earth's surface, or about once per millennium on the land. Even if 10% of Earth's land were densely populated, this amounts to a hit on a city only once in 10,000 years.

There are other ways cities can suffer the effects of an impact. Were a Tunguska-class object to land in the ocean, it would produce tsunamis with tremendous potential for destruction. Tsunamis travel much farther from the impact site than the direct blast wave, producing widespread destruction in coastal areas thousands of kilometers distant.

For every person killed directly by the impact, about ten more would be killed by an impact-induced tsunami. Yet even the tsunami risk is less than that of succumbing to an ecological disaster brought about by still larger impacts, which could trigger crop loss and starvation on a global scale. Your risk of dying from such a global event is about ten times greater than that from a tsunami, or 100 times greater than that of a direct hit.

But a simple comparison of risk between impacts and their secondary effects doesn't tell the whole story. No other natural disaster we know of has global dimensions. Even the worst earthquake or flood affects only a few percent of Earth's population. An impact-induced ecological catastrophe, however, could kill a billion people and destabilize civilization. It would end the world as we know it.

In other words, larger impacts, ones caused by asteroids as small as 100 meters right on through the 6-km or-larger Great Extinctors, pose the greatest risk to humanity. Even though such massive hits are extremely rare, their global consequences bode worse for humanity than the cumulative effects of smaller and more frequent hits.



Risk is a matter of perception

Where common accidents might kill a few people, exceedingly rare, large impacts will destroy the human race.

Phil Kirchmeier after Morrison and Chapman

Since the chance of a major impact in our lifetime is so low, impacts are a danger most people ignore. Therein lies the problem with statistical arguments. Being human, the weight we assign to threats in large part determines how "real" they become in our collective mind. Either there is an asteroid up there in an orbit that will lead to a collision with Earth within the next century, or there is not. If not, then we have nothing to worry about. But if there is a big rock up there with our name on it, we had better find it and take action to protect ourselves.

There are probably 1,000 near-Earth objects (NEOs) — whose orbits cross that of Earth's — large enough to cause a global environmental collapse if they hit. But of these 1,000 objects, we have actually discovered fewer than 100, less than 10 percent. We know from orbital calculations that none of these 100 objects threaten Earth. But that says nothing about the 900 we haven't discovered. One of them could hit at any time, perhaps without warning.

Earth's Guard is Down

The sad reality is that we humans are not doing a very good job of policing the inner solar system, where threatening asteroids lurk undetected. Virtually all the discoveries of near-Earth objects are made by just four teams of astronomers, one of which is terminating its search (see "They Stand On Guard For Thee"). This leaves only a handful of people — smaller than the staff of one McDonald's restaurant — to carry out the beginnings of what could be an effort to save humanity from the next mass extinction.

While the search effort continues, albeit haltingly, another facet of the humans-versus-asteroids story is gathering momentum. Former Cold War adversaries have teamed up to explore ways of deflecting or even destroying threatening asteroids (see "Cold War Weaponeers Gaze Skyward").

But the first step in any asteroid defense program is to carry out a census of potentially threatening objects, beginning with the most dangerous — those larger than 1 km in diameter. In 1990, Congress requested that NASA study ways to increase the discovery rate of these near-Earth objects. An international team of astronomers proposed a program called the Spaceguard Survey, designed to obtain a complete census of these larger asteroids.

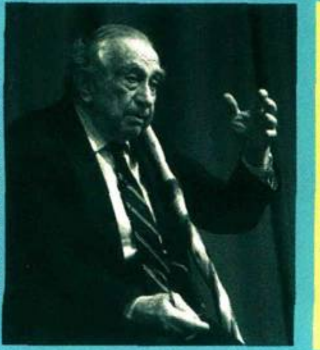
The results were reported to the Congress in 1992, and NASA made available about $1 million in additional funds to upgrade existing search programs. At the same time, the International Astronomical Union appointed a working group on near-Earth objects to promote international cooperation in this search. Since everyone on Earth is at risk from cosmic impacts, it seemed only reasonable to share the cost of the survey.

And even before the dust of Comet Shoemaker-Levy 9's impact completely settles on Jupiter, Congress is asking NASA to act, this time with a greater sense of urgency. They want the agency to work with the US Air

Cold War Weaponeers Gaze Skyward

It was called the *International Technical Meeting on Active Defense of the Terrestrial Biosphere from Impact by Large Asteroids and Comets.* What it dealt with, in fewer words, was how to defend the Earth against cosmic impacts.

Last May's workshop at the Department of Energy's Livermore National Laboratory in California was the third in a series of international meetings on planetary defense sponsored by nuclear weapons labs in the United States and Russia. Experts in nuclear weapons and missile defense systems, as well as a sprinkling of astronomers and government policy makers, pondered what to do if a comet or asteroid were on a collision course with Earth. It turns out there are two options: Change the threatening object's orbit or smash the offending meteoroid into bits that would burn up in Earth's atmosphere.

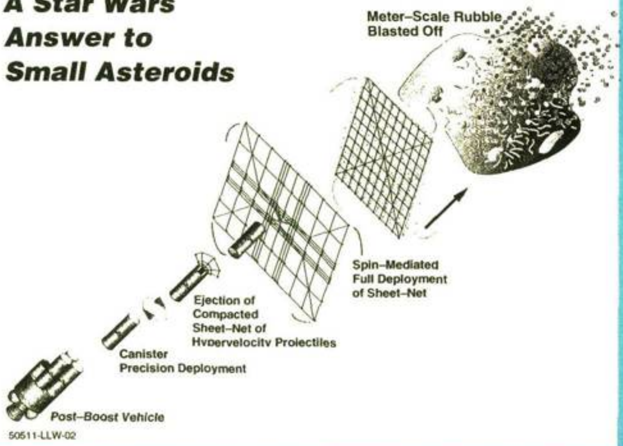


Lawrence Livermore Naitonal Laboratory

"Monster waves would cause billions of dollars in damage and kill thousands — perhaps many thousands — of people."

— Dr. Edward Teller
Father of America's
Hydrogen Bomb

A Star Wars Answer to Small Asteroids


Meter-Scale Rubble Blasted Off
Spin-Mediated Full Deployment of Sheet-Net
Ejection of Compacted Sheet-Net of Hvpervelocitv Proiectiles
Canister Precision Deployment
Post-Boost Vehicle
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Lawrence Livermore National Laboratory

Sessions focused primarily on dealing with objects greater than 1 km in diameter, since they pose the greatest risk to life on Earth. Nuclear explosives would be better at deflecting asteroids of this size, assuming an asteroid search could provide a lead warning of years or decades.

Some astronomers advocate quick development of such a survey, contending that a nuclear defense system could be developed after such a threat is found. However, many weapons scientists feel we should build anti-asteroid defenses now and test them against non-threatening asteroids to hone our deflect-or-destroy abilities.

In addition to the nuclear options, Star Wars-based technology might physically "slice up" asteroids with diameters of tens of meters. Indeed, some scientists think this approach could eventually deal with larger objects as well.

One of the strongest proponents of testing is Edward Teller, the father of America's hydrogen bomb. He gave a banquet talk on the "need for experiments on comets and asteroids." Teller focused on the measurable likelihood that a small asteroid, perhaps the size of a football field, could hit in the 21st century. Such an impact would create tsunamis large enough to devastate continental coastlines. Monster waves, he said, would "cause billions of dollars in damage and kill thousands — perhaps many thousands — of people." In his opinion, protection against such a catastrophe justifies a defense program in the range of "perhaps $100 million per year."

Such a program could ride the coattails of Clementine, the Pentagon's successful mission to the Moon. Defense scientists remain interested in similar scientific missions to asteroids, leading toward active experiments, both nuclear and non-nuclear. Missions might use decommissioned 300 Russian SS-18 missiles. The reconfigured rockets could launch small payloads to asteroids.

But such work must happen between now and the year 2002; all SS-18s have to be destroyed, as mandated by the START nuclear weapons reduction treaty. After years of contributing to the nuclear stalemate, perhaps these Cold War rockets might hasten the day when Earth can protect itself against rogue comets and asteroids.

Force, which already maintains a network of telescopes used to track faint Earth satellites, to find a way to carry out an NEO survey within the next decade. A team led by Gene Shoemaker is currently preparing a report on ways to carry out this mandate.

So in a way, Earth's fragile lifeforms are finally coming to grips with a persistent problem. For the first time in our planet's history, through the intellect of its human species, life can avoid a fate that up to now has been inevitable. After observing the geological evidence for mass extinctions and bearing witness to Jupiter's horrific pounding, we the people of Earth are getting positioned for action.

Earth, the planet of life, need never be a target again. ☐

David Morrison heads the Space Science Division at NASA's Ames Research Center in California, and recently received the agency's Outstanding Leadership Medal for his work on impact hazards.

A Milestone in Fornax

By taking aim at a cluster of galaxies in the constellation Fornax, astronomers are poised to make their best estimate yet of the age of the universe.

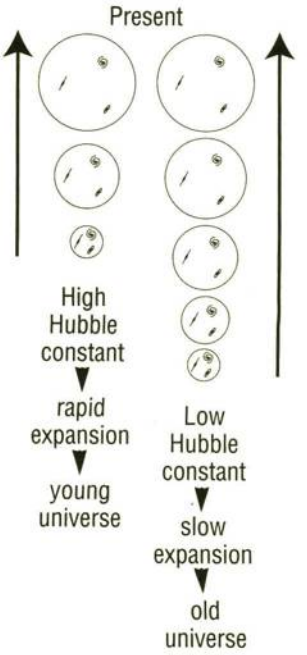
by Ken Croswell

Hubble constant: *the rate at which the universe is expanding, usually expressed in kilometers per second per megaparsec (one megaparsec equals 3.26 million light-years). A Hubble constant of 50 means the universe is expanding 50 kilometers per second faster for each megaparsec farther in space.*

Welcome to the next battle in the fierce Hubble war — the great controversy over the age of the universe. Ever since Edwin Hubble discovered the universe's expansion in the late 1920s, astronomers have struggled to determine just how fast that expansion is occurring. This rate determines the size and age of the universe. The faster the expansion rate, called the Hubble constant, the younger the universe must be. For decades, though, astronomers have measured wildly different values for this crucial number, some finding it half as large as others do.

Last year, in a historic breakthrough, astronomers used two galaxies in the great Virgo Cluster to obtain what many consider the current best estimate of the Hubble constant. But that work hardly ended the debate, and astronomers are now turning toward the southern sky to snare a cluster of galaxies that will prove even more crucial than Virgo: Fornax. The results from Fornax may possibly overturn last year's results, saving astronomers from the dilemma of having to explain why the universe appears to be younger than its oldest stars.

Expansion and Age

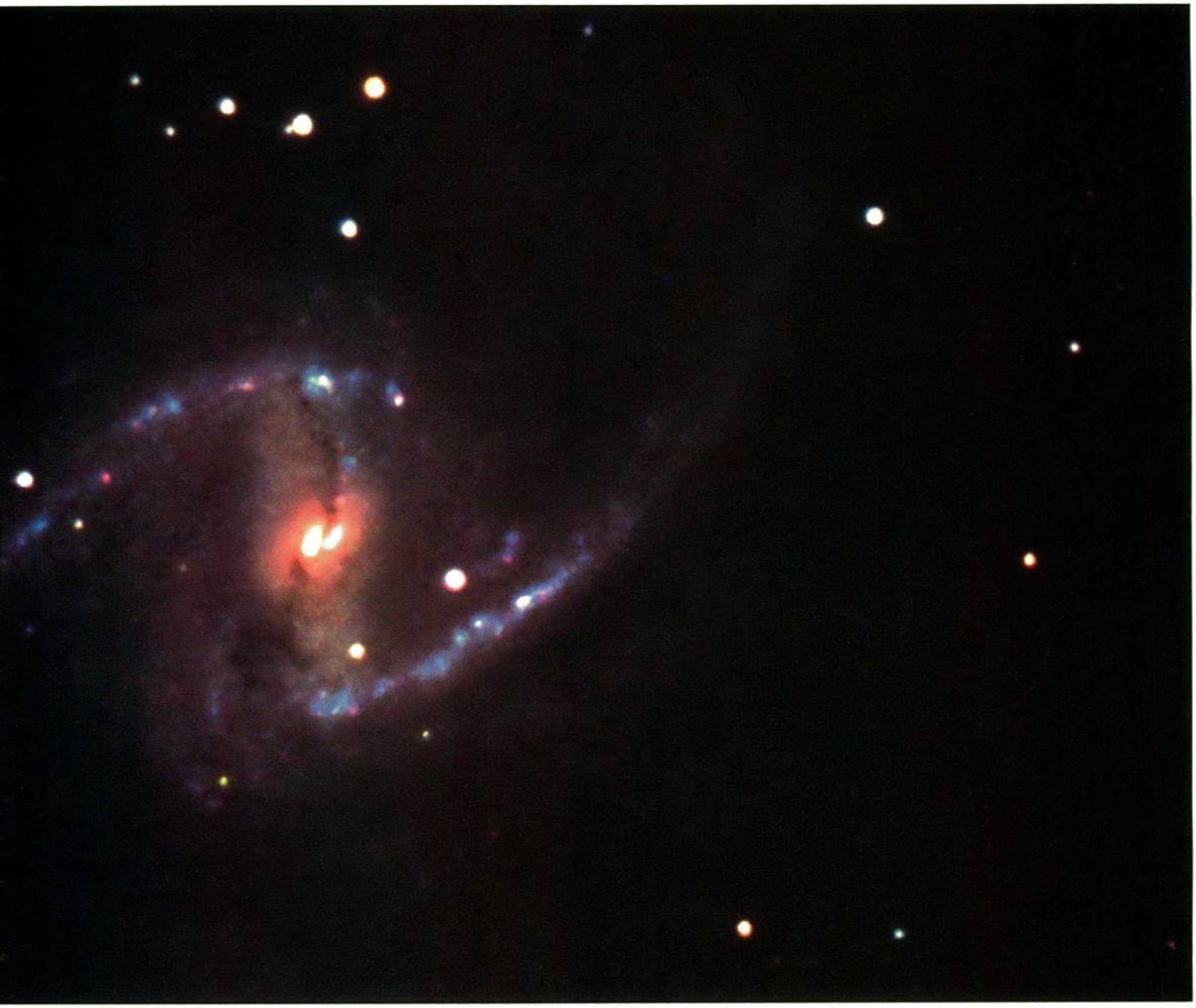


Although the Fornax Cluster is about as far away from us as the swarm of galaxies in Virgo, it isn't nearly as famous. Fornax has just a fifth as many galaxies as Virgo, and it lies in the southern sky, so observers at mid-northern latitudes glimpse the cluster only briefly during autumn and early winter. Yet the Fornax Cluster is the next battleground in the long struggle to determine the Hubble constant.

"Whatever Fornax gives for the Hubble constant should carry a lot more weight than any single determination from Virgo ever could," says Caltech's Barry Madore, a member of the team measuring the distances to both clusters. "I think that had we all grown up in the Southern Hemisphere, we would have done Fornax first. Virgo has always been that stepping-stone that people have lusted after from the north, but a rational case could have been made for doing Fornax first."

Whether astronomers look to Virgo or Fornax, much of modern cosmology is riding on the determination of the Hubble constant. Logically, the universe must be older than its oldest stars. But recent determinations of the Hubble constant have turned up numbers that imply the impossible, that the universe is *younger* than its oldest stars.

According to stellar evolution models, the oldest stars in our Galaxy are 15 billion years old, give or take a couple billion. That's no problem if the Hubble constant is low. A low Hubble constant means the universe is expanding slowly and has taken plenty of time to reach its present size, so it must be old. For example, if the Hubble constant is as low as 50 kilometers per second per megaparsec (one megaparsec is 3.26 million light-years), the universe is between 13 and 18 billion years old. That age is probably old enough to accommodate the oldest stars.



James R. Foster

THE NEXT BATTLEGROUND in the great Hubble constant controversy is NGC 1365 in Fornax.

But a higher Hubble constant means the universe has expanded more rapidly, so it took much less time to reach its present size. Many astronomers have found that the Hubble constant is around 80. This value implies that the universe is only 8 to 11 billion years old, younger than the estimated ages of the oldest stars. Clearly, something is wrong: either the age of the universe or the age of those stars — or, just possibly, modern cosmology itself.

Virgo: A Bridge Too Near

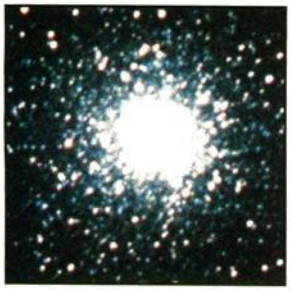
To establish the Hubble constant, astronomers must measure the distances to other galaxies and the velocities with which they speed away from us. Velocities are easy to determine: They come from the shifts of dark lines in the galaxies' spectra, the so-called redshifts. The measured velocities are usually accurate to better than 1 percent.

Galaxies move about inside their host cluster, so astronomers must correct for this motion. They remove this effect by averaging the recessional velocity for many of the galaxies in the cluster. This tells astronomers how fast the cluster as a whole is receding from us. Next, they divide the cluster's velocity by its distance from us to get the universe's expansion rate, the Hubble constant. Thus, if one observes a velocity for a cluster, the *smaller* its distance, the *larger* the Hubble constant — and the *younger* the universe.

Unfortunately, in order to probe the Hubble constant, a galaxy must be far away from us; otherwise, the gravitational pull of the Milky Way and other galaxies perturbs it so much that most of its velocity does not arise from the universe's expansion. As a result, only distant galaxies can reveal the Hubble constant. But measuring their distances is extremely difficult.

The Virgo Cluster is far enough away that most of its velocity arises from the expansion of

***Redshift:** changes in a galaxy's spectrum caused by the expansion of space that indicate it is moving away from us. In general, the farther the galaxy, the greater its redshift.*



Bill Iburg

SOMETHING'S WRONG. The oldest stars in this globular cluster, M15, are thought to be about 15 billion years old. Hubble constant measurements from M100, however, put the universe's age at 8 to 11 billion years.

the universe (see "How Far to Virgo?" March 1995). In 1994, ground-based observations determined that one Virgo galaxy, NGC 4571, lies 49 million light-years away, and Hubble Space Telescope observations put another Virgo member, M100, at 56 million light-years. These distances are small and imply a large value for the Hubble constant, and thus a young age for the universe. For example, the M100 team concluded that the Hubble constant is 80 ± 17 kilometers per second per megaparsec, which suggests the universe is younger than its oldest stars.

But as soon as that result was announced, those astronomers who favor a lower Hubble constant blasted it. Some Virgo galaxies are closer to us than others, argued the critics. The distance to M100, they said, does not reveal the distance to the entire Virgo Cluster. Instead, M100 might lie closer to us than the bulk of the cluster. The M100 team itself pointed out this very problem in their paper and looked ahead to another cluster — Fornax.

The Virtues of Fornax

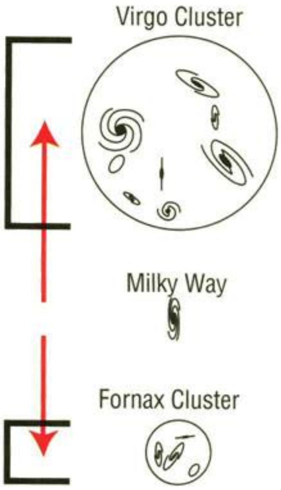
The depth problem does not plague the Fornax Cluster. "Fornax is a more compact cluster, only about 15 percent of the size of the Virgo Cluster," says Wendy Freedman of the Carnegie Observatories in Pasadena, California, who headed the team that measured the distance to M100. One galaxy in Fornax should indicate the cluster's average distance more accurately than M100 did for Virgo. Although Freedman and her colleagues measured a precise distance to M100, they concluded that their distance to the center of Virgo itself was uncertain by 20 percent because M100 may not be at the cluster's core. This accounts for most of the ± 17 margin of error in their Hubble constant calculation. Because Fornax is much more concentrated, Freedman anticipates that the uncertainty arising from this depth problem will probably be less than 10 percent.

Fornax has other virtues too. Like Virgo, it is far enough away that most of its velocity arises from the expansion of the universe, so astronomers can use its distance and velocity to measure the Hubble constant directly. The Hubble constant derived from the Fornax Cluster will therefore check the Hubble constant derived from the Virgo Cluster.

Furthermore, Fornax lies on the opposite side of the sky from Virgo. Virgo is north of the Milky Way's plane whereas Fornax is south, so the two clusters probe the universe's expansion in opposite directions. This is important because the Virgo Cluster is so massive that its gravity retards the universe's expansion in its neighborhood, which includes the Milky Way. Consequently, astronomers must "correct" Virgo's velocity and also that of Fornax, which Virgo is pulling us away from, in order to derive the Hubble constant from either cluster. If that correction is too high or too low, Virgo and Fornax will provide inconsistent Hubble constants. Indeed, because Virgo is pulling us away from Fornax, the Fornax velocity is greater than Virgo's even though both clusters are thought to be equidistant from us.

Once the Hubble astronomers decided to observe Fornax, they had to decide which of Fornax's galaxies offered the best target for their distance measurement. Spiral galaxies are key for measuring the Hubble constant. Unlike ellipticals, spirals possess the pulsating stars that reveal precise distances — *Cepheid variables*. A Cepheid is an excellent yardstick because the longer its pulsation period, the greater the star's

The Depth Problem



Fornax is so compact that any one galaxy provides a good estimate of the cluster's average distance. This is not true of the much larger Virgo Cluster. This problem complicates astronomers' efforts to calculate the Hubble constant.

Luke Dodd

A COSMOLOGICAL LINCHPIN, the Fornax Cluster in the Southern skies. NGC 1365 is in the lower-left hand corner.

true brightness. Comparing the star's real brightness with the apparent brightness yields the distance to the Cepheid and its host galaxy.

But because Cepheids are short-lived, they appear only in gas-rich galaxies, such as spirals, that create new stars. In contrast, elliptical galaxies have consumed most of their gas and usually don't create new stars. Last year, when astronomers determined the distance to the Virgo Cluster, they used Cepheids in NGC 4571 and M100, both of which are spirals.

Unfortunately, Fornax has far fewer galaxies than Virgo — a 1988 study found only 235 in Fornax versus 1,170 in Virgo — and Fornax also has a much lower proportion of spiral galaxies relative to ellipticals. The 1988 survey listed only 17 spirals, and just a few of these will satisfy astronomers' needs. For example, an edge-on spiral won't do, because its stars appear too crowded together and because gas and dust in the galaxy's disk mask the Cepheids. In addition, spirals differ in their star-producing vigor. Only spirals that create large numbers of new stars abound with Cepheids.

The Verdict from Fornax

By applying these and other selection criteria, astronomers using the Hubble Space Telescope have chosen the first Fornax galaxy in which to hunt for Cepheids. That galaxy, NGC 1365, is a barred spiral that gives birth to many stars and should thus have plenty of Cepheids. It also happens to be one of the most beautiful galaxies in the sky.

But the Hubble team denies that the galaxy's beauty played any role in its selection. "We've only done that once," recalls Robert Kennicutt of the University of Arizona. "Remember those

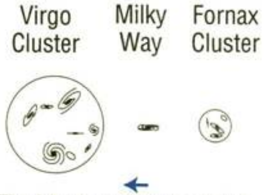
Cepheid variable: *a type of star that fluctuates in brightness. The rate at which the Cepheid varies tells astronomers the true brightness of the star. By comparing a Cepheid's true and apparent brightness, astronomers can calculate how far away it is.*

James R. Foster

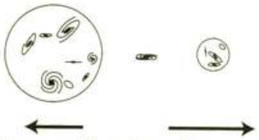
A FUTURE HUBBLE TARGET: M95 in Leo.

***Galaxy cluster:** an assemblage of hundreds to thousands of galaxies.*

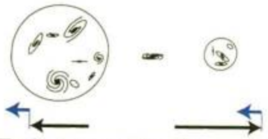
Velocity Correction



The Virgo and Fornax clusters are roughly equidistant but lie in opposite directions. The more massive Virgo pulls harder on our own galaxy.



Because Virgo's pull is stronger than Fornax's, Virgo appears to be receding from us slower than it should, while Fornax's velocity appears faster than it should.



To factor out Virgo's stronger pull, astronomers add a velocity to Virgo and subtract that same velocity from Fornax. If they use the correct velocity, the two clusters will yield the same Hubble constant.

beautiful pictures of M100? That was one time when we did take aesthetics into account." M100 pleased NASA, which after the Hubble Space Telescope was repaired, wanted to show the public a galaxy that was both beautiful and scientifically important.

If anything, NGC 1365 is even more stunning than M100. NGC 1365 appears as bright in telescopes as M100, but it also has a large central bar joining two majestic spiral arms that sweep out in opposite directions over a vast expanse of space. Hubble's images of NGC 1365 may disappoint, however, because like M100, the galaxy is so huge that the telescope can capture only a fraction of it with one exposure. Indeed, NGC 1365's large apparent size might suggest that it lies in front of the Fornax Cluster. But the galaxy's velocity matches the cluster's, so it should be a bona fide member.

In 1996, as a check, the Hubble team will observe a second Fornax galaxy, probably the much smaller spiral NGC 1425. This second measurement will help pin down the distance to Fornax. The astronomers will also observe two additional galaxies in Virgo to firm up that cluster's distance.

The Hubble team hopes to determine NGC 1365's distance — and a corresponding value for the Hubble constant — by early next year. If the galaxy turns out to be relatively nearby, between 40 and 50 million light-years away, then the derived Hubble constant will be around 80, confirming the Virgo work. This would once again imply a universe younger than its oldest stars. But if the galaxy is much farther — 70 or 80 million light-years away — then that will favor a lower Hubble constant of around 50, which will free cosmologists from having to explain how stars can be older than the universe.

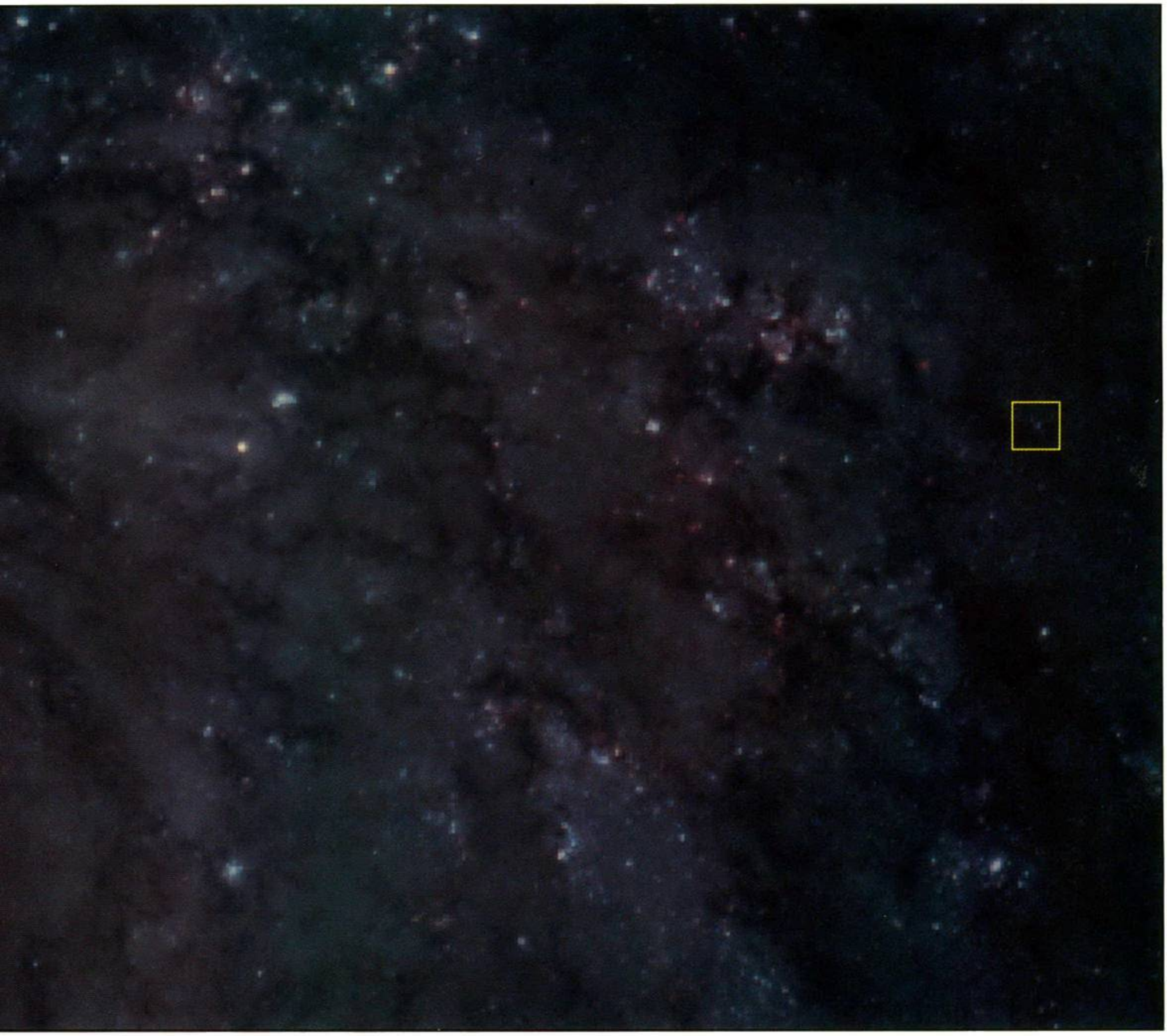
"It's the first consistency check on the Virgo result," says Kennicutt. "If we get a distance that is much farther than we expect, based on Virgo, then that's going to raise eyebrows and hint that maybe M100 was in front of the Virgo Cluster. If we get a much shorter distance yet — even higher values of the Hubble constant — then people are going to look at NGC 1365 and say, 'My goodness, that's a really large galaxy. Maybe *it's* the problem; maybe it's in front of Fornax.' Or maybe it'll give an answer that's right on, 80 again, in which case it's a confirmation, but a preliminary one, of the Virgo result."

The Limitations of Fornax

Although Fornax will be crucial in the determination of the Hubble constant, the cluster has its limitations. "Fornax is one cluster," cautions Wendy Freedman. "I don't see this as being the Hubble constant any more than I see Virgo as being the Hubble constant. There's some tendency for people to say that Virgo's going to answer it and that Fornax is going to nail it. Eventually, with enough data, the problem *will* be nailed. But individual clusters or galaxies are not going to convince me, at least, that we really do have a value of the Hubble constant accurate to 10 percent."

Kennicutt agrees. "Although we certainly view the NGC 1365 distance as the next milestone in the program, the program doesn't rest on just a few galaxies like M100 or NGC 1365. These galaxies have a lot of appeal, but the distance to NGC 1365 is not going to make or break the Hubble constant."

A combination of the Virgo and Fornax measurements, along with several upcoming Hubble Space Telescope observations, will indeed make or break the Hubble constant. In fact,



J. Trauger, JPL, and NASA

determining the Hubble constant was the primary *raison d'être* for the space telescope. Hubble is examining Cepheids in 15 to 20 nearer galaxies. The distances to these galaxies will calibrate several distance-measuring techniques that the astronomers will apply to galaxies far beyond Virgo and Fornax. These other distance indicators include planetary nebulae, certain types of supernovae, and the rotation of spiral galaxies (see "Candles to Light the Night," September 1994).

Furthermore, the team will check their fundamental yardstick, the Cepheids themselves. One worry is that differing chemical composition among Cepheids may alter their luminosities, which would compromise our ability to gauge distances by using Cepheids. To test for this problem, the Hubble Space Telescope will compare Cepheids that have different chemical compositions but lie in the same galaxy. Since all such Cepheids are nearly the same distance from Earth, they should yield the same answer for the galaxy's distance. If they don't, that will signal trouble.

Kennicutt says that only after the team completes such tests and checks, which should take two to three years, will they really have the final answer for the Hubble constant. "But we'll have some mighty good hints along the way," he says, "and NGC 1365 in Fornax will certainly be an important one." Stay tuned. ☐

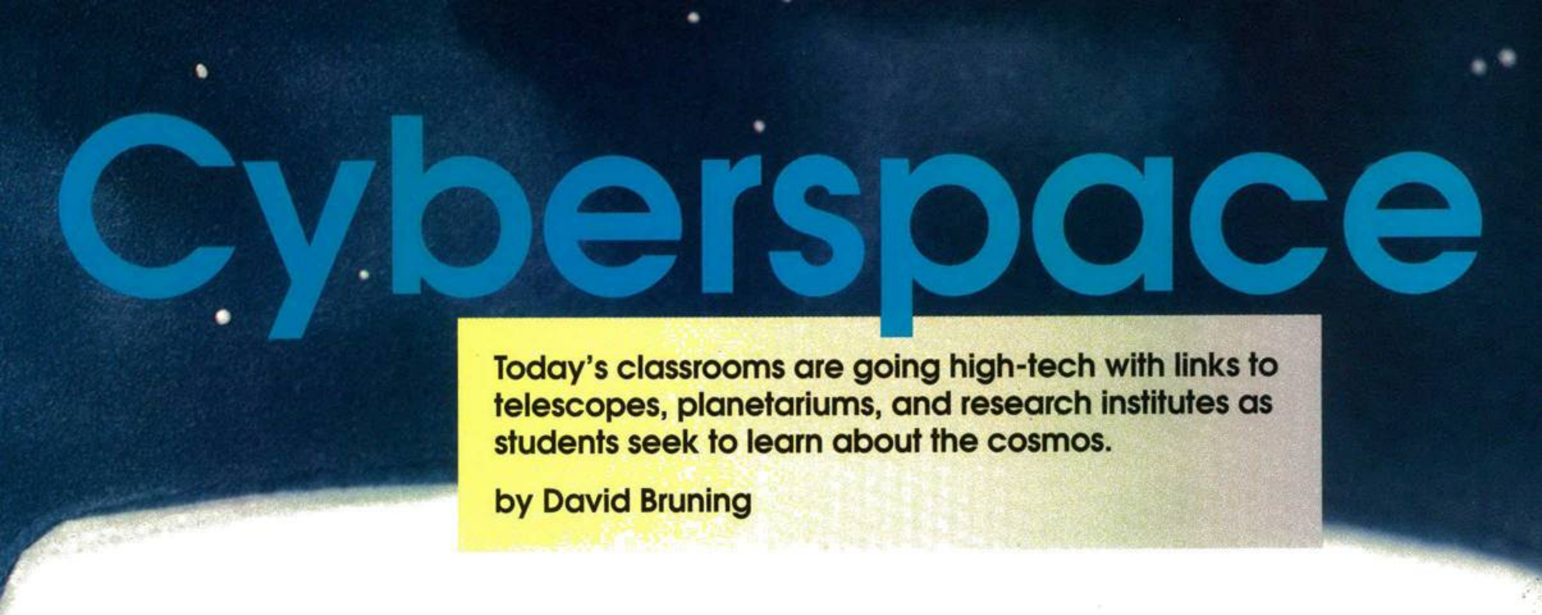
Ken Croswell received his Ph.D. in astronomy from Harvard University and is the author of The Alchemy of the Heavens *(Doubleday/Anchor, 1995), a book about the Milky Way Galaxy and its connection to the larger universe.*

STELLAR YARDSTICKS, Cepheid variables, appeared in this Hubble Space Telescope image of M100 in Virgo. Astronomers used the M100 Cepheids to calculate the Hubble constant. A Cepheid appears in the box.

Cosmology: *the study of the formation and evolution of the universe.*

Students in

Bruce Bond



Cyberspace

Today's classrooms are going high-tech with links to telescopes, planetariums, and research institutes as students seek to learn about the cosmos.

by David Bruning

The Internet is the rage in corporate America and is quickly catching on with home computer users. It's no different in the classroom, where teachers are discovering that they can use the information superhighway to share lesson plans, experiments, and teaching strategies, plus get quick responses from experts to questions they have about facts and concepts. Students, too, can cruise the Net to explore interactive encyclopedias, find images and resource materials for term papers, and even perform experiments with kids in other states or countries.

Astronomy is one of the areas represented on the Internet's world-wide network of computers that has rich offerings for teachers and students. NASA, museums, observatories, and planetariums share hundreds, if not thousands, of electronic images, databases, and documents. The Internet also provides access to remote telescopes that run robotically. Students can link to the scope to see what astronomers are looking at tonight or even run the telescope themselves.

This high-tech approach will undoubtedly change education and, if done properly, will mold a new generation of scientists and astronomy enthusiasts. The key, as always, is to let students have hands-on experience and let their curiosity drive their educational experience. After all, isn't that how scientists approach their work?

The Internet connects users together in two basic ways. One is electronic mail, where one person sends another a text message using a mail program such as *Eudora*. The message goes over phone lines to the recipient's Internet address; for example, dbruning@astronomy.com.

Users also connect to the Internet through the World Wide Web. The Web isn't a collection of computers but rather a collection of documents stored on computers. Users access the Web through a browsing program such as *Mosaic* or *Netscape*. Individual documents contain links (called Uniform Resource Locators or URLs; their addresses commonly start "http://") to other documents, so a document about ultraviolet astronomy may link the reader to other ones about satellites, telescopes, and research institutes. Because the Web emphasizes content and not hardware, it has become the preferred mode of access for connecting to Internet resources. (For more information about getting on the Internet, using the World Wide Web, and finding astronomy URLs, see "Blasting Along the Infobahn," June 1995.)

Connecting students directly to researchers is what NASA's Passport to Knowledge program is all about. Starting this September, students can take an electronic field trip on the Kuiper Airborne Observatory (see "Telescopes That Fly," November 1994). To prime teachers and students for the adventure ahead, they'll view a half-hour videotape on infrared astronomy and the airborne observatory.

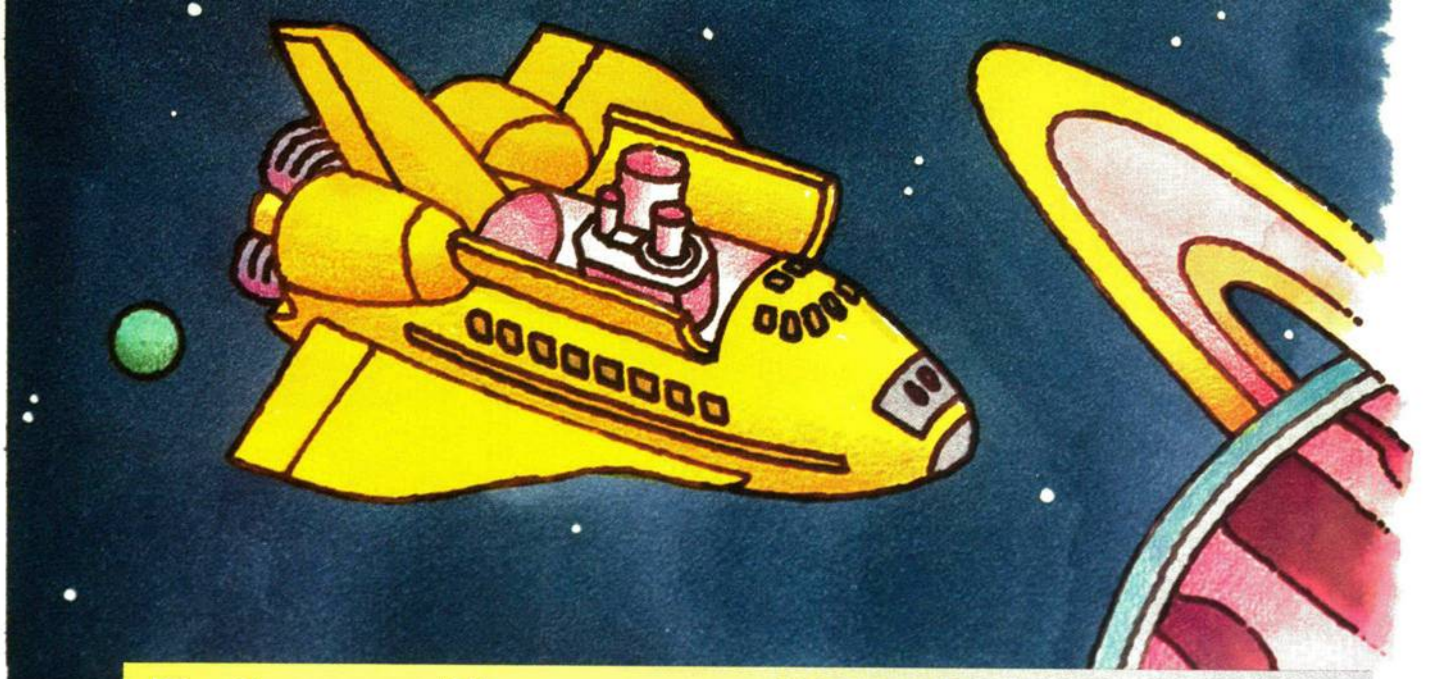
In October, as astronomers observe planets, stars, and galaxies with Kuiper's infrared telescope, students at select schools, planetariums, and science museums will follow the action using interactive video and Internet links. A student team onboard the aircraft will relay to their counterparts on the ground what it's like observing at 41,000 feet. Two flights will occur: a 2.5-hour day flight "to observe" primarily Jupiter (scheduled for Thursday, October 12) and a 5-hour night flight "to observe" Saturn, star-forming regions, and the galaxy M33 in Triangulum (scheduled for Friday, October 13). Some of the museums and planetariums will have overnight camps for students participating in Kuiper's night flight.

Students at schools without an Internet connection can view the proceedings on videotape after the flights. NASA has produced a teacher's guide and will provide online supplementary materials on the Internet. These materials include instructions on how to follow the Galileo spacecraft's encounter with Jupiter beginning this December.

Kids are eager to learn astronomy. Their fascination with computers makes the Internet an ideal tool for harnessing their imagination.

Next spring, Passport to Knowledge will feature the Hubble Space Telescope. To get more information about the Live From the Stratosphere program, send a request via e-mail to info-lfs@quest.arc.nasa.edu or open the Web document at **http://quest.arc.nasa.gov/livefrom/Stratosphere.html**. For those without Internet access, call (800) 626-5483.

Although now officially over, the Astro-2 mission in March showed how useful the Internet can be to showcase the events of a space shuttle mission. From March 2 through March 18, more than 200,000 people



Education on the Internet

Use a Web browser such as Mosaic or Netscape to access these resource locations.

Uniform Resource Locator	Resource
http://boas3.bo.astro.it/dip/Museum/MuseumHome.html	Astronomical Museum in Bologna, Italy
http://fits.cv.nrao.edu/www/astronomy.html	Astro Web
http://info.itp.berkeley.edu/Vol1/Contents.html	Interactive Physics
http://lcweb.loc.gov/homepage/lchp.html	Library of Congress
http://marvel.stsci.edu/net-resources.html	Astro Web
http://maxwell.sfsu.edu/asp/amateur.html	List of local astronomy clubs
http://quest.arc.nasa.gov	NASA's K-12 Internet Initiative
http://rs560.cl.msu.edu/weather/interactive.html	Weather
http://seds.lpl.arizona.edu/messier/Messier.html	Images of Messier deep-sky objects
http://seds.lpl.arizona.edu/nineplanets/nineplanets/nineplanets.html	Tour of the solar system
http://skyview.gsfc.nasa.gov/skyview.html	Skyview maps at different wavelengths
http://spacelink.msfc.nasa.gov	NASA's Spacelink for news and images
http://sunsite.unc.edu/lunar/	Lunar Institute of Technology
http://sunsite.unc.edu/lunar/alien.html	SETI game
http://www.cea.berkeley.edu/Education/SII/pilot.html	Science On-Line; virtual museums
http://www.c3.lanl.gov/~cjhamil/Browse/mars.html	Interactive Mars map
http://www.c3.lanl.gov/~cjhamil/SolarSystem/	Views of the solar system
http://www.eia.brad.ac.uk/rti/automated.html	Robotic telescopes
http://www.eia.brad.ac.uk/btl	Multimedia guide to stars and galaxies
http://www.exploratorium.edu	San Francisco's Exploratorium
http://www.fourmilab.ch/earthview/vplanet.html	Earth viewed as a planet
http://www.gettysburg.edu/project/physics/clea/CLEAhome.html	Lab exercises in astronomy
http://www.gsfc.nasa.gov/NASA_homepage.html	NASA home page
http://www.halcyon.com/cairns/physics.html	Educational resources
http://www-hpcc.astro.washington.edu/k12/ask.html	Answers to astronomical questions
http://www-hpcc.astro.washington.edu/k12/astroimage.html	Astronomical Images
http://www-hpcc.astro.washington.edu/k12/astroindex.html	Educational resources
http://www-hpcc.astro.washington.edu/k12/planetaria.html	Planetariums
http://www.jpl.nasa.gov	Jet Propulsion Lab home page
http://www.jpl.nasa.gov/educ/education.html	JPL Educational Outreach
http://www.ksc.nasa.gov/history/history.html	History of spaceflight
http://www.nas.nasa.gov/NAS/SpaceSettlement/Contest/contests.html	Space Settlement design contests
http://www.physics.mcgill.ca/physics_services/physics_services.html	Physics resources
http://www.physics.sfsu.edu/asp/asp.html	Astronomical Society of the Pacific
http://www.sel.bldrdoc.gov/today.html	Solar image for today
http://www.seti-inst.edu/ed-top.html	Educational resources
http://www.stsci.edu/top.html	Space Telescope Information Service
http://www.stsci.edu/exined-html/exined-home.html	Hypercard books for Mac
http://www.w3.org	Mother of all WWW home pages
http://www.w3.org/hypertext/DataSources/bySubject/astro/educational.html	Educational resources

visited the Astro-2 World Wide Web site to learn about the ultraviolet astronomy mission. Viewers could examine the flight deck and instruments and watch observations as they were being made. Internet users with a Web-browsing program can still access this site at **http://astro-2.msfc.nasa.gov**.

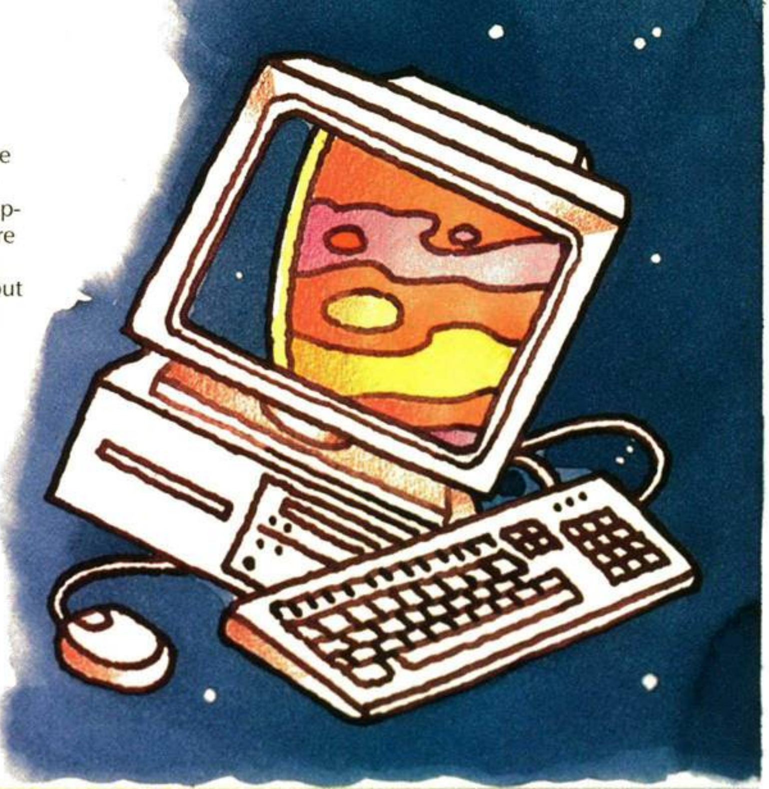
Hands-on Universe is a high-school program that enables students to participate in actual research programs, transforming science class from learning facts to experiencing science firsthand. Developed by the Lawrence Berkeley Laboratory and the astronomy department and Space Sciences Laboratory of the University of California at Berkeley, the program uses data sets from professional telescopes and links students, teachers, and professional astronomers together via computer. The students can obtain images real-time from the university's Leuschner Observatory and then work with astronomers in an apprentice role to process the images and analyze the data. For more information, search the Web site at **http://www.lbl.gov/Education/HOU.html** or contact Elizabeth Arsem at (510) 486-5235, e-mail arsem@lbl.gov or Carl Pennypacker at (510) 486-7429, e-mail pennypacker@lbl.gov.

The Mount Wilson Institute also has a remotely controlled telescope. The 24-inch scope, on loan from Caltech, has already been used by schools on both coasts. In conjunction with use of the scope, Mount Wilson's Telescopes In Education program will have a teaching database containing lesson plans, questions and answers, and digitized images. The developers are designing these lessons to investigate and apply concepts rather than just enumerate theories and provide historical background about a subject. Gil Clark is the contact person for the TIE program; call (818) 793-3100, fax (818) 793-4570, or e-mail tie@mtwilson.edu.

A similar program using a radio telescope is under study. NASA is considering loaning a radio dish at its Goldstone site for use in this Radio Telescopes in Education program. To be operated by the Apple Valley Science and Technology Center in Apple Valley, California, the scope will enable students to see for themselves astronomical objects at a different wavelength. Call the Apple Valley Science and Technology Center at (619) 242-3514 for more information.

Trips to a museum always excite kids because they get a chance to see a Moon rock or climb into an actual space capsule. Cybermuseums are almost as neat — you can't touch anything, but you can go to lots of museums across the country or around the world that you might never visit otherwise.

For example, let's take a "field trip" to the National Air and Space Museum by opening the Web location



Visit the Exploratorium

http://www.exploratorium.edu

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TAKE YOUR KIDS ON A TRIP to a virtual museum. The electronic halls of the Exploratorium in San Francisco, California, lets them explore different aspects of science such as how light behaves. They can download the movies and photos without the crowds.

http://www.nasm.edu/NASMAP.html. This reveals a map of the Air and Space Museum. Viewers can click on any gallery to explore images of what the real museum's displays look like. Explanations accompany the image in the same way placards describe the display in the museum, although often the virtual museum provides more information or links to other Web sites. Okay, the images aren't three-dimensional (yet!), but the tour is still satisfying and educational.

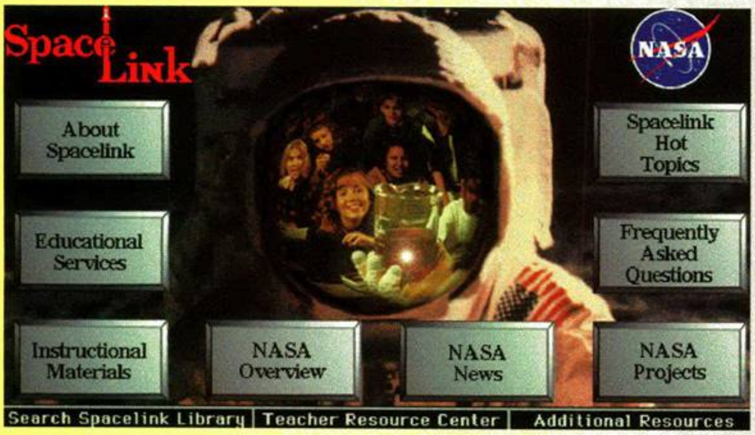
Some museums are producing cooperative Web exhibits along with an observatory or space program. Science Information Infrastructure is a program that attempts to bridge the gap between current astronomical research and students through the participation of science museums. It consists of 14 research institutes, science museums, and corporations, including the Smithsonian Astrophysical Observatory, the Center for Extreme Ultraviolet Astrophysics at the University of California in Berkeley, Adler Planetarium in Chicago, and the Lawrence Hall of Science in Berkeley, California. Some of the plans on their web site include lessons on the impact of Comet Shoemaker-Levy 9 on Jupiter, astronomical satellites, and the electromagnetic spectrum. In the last, students act as prosecutors, defense attorneys, and jury members in the case of wavelengths having potentially damaging properties. Reach SII at **http://www.cea.berkeley.edu/Education/SII/pilot.html**.

The Internet is also a great place to learn about new ideas in education. Two organizations in this country coordinating educational efforts in astronomy are the American Astronomical Society and the Astronomical Society of the Pacific. To read about the American Astronomical Society's new education initiative, go to the Web location **http://earth.ast.smith.edu/ED/ed.html**. Among other things, the society will be developing an electronic database and resource network for astronomy education.

The Astronomical Society of the Pacific, in cooperation with the American Astronomical Society, publishes a teacher's newsletter called *Universe in the Classroom*. Teachers can subscribe to this free newsletter by sending a request on school stationery to Universe in the Classroom, ASP, 390 Ashton Avenue, San Francisco, CA 94112. Back issues of the

Link to NASA

http://spacelink.msfc.nasa.gov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NASA Projects
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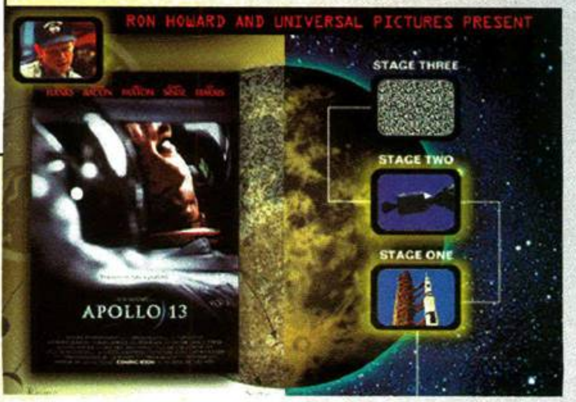
Teacher Resource Center
Additional Resources

SPACELINK CONNECTS teachers and students to the latest space news. It also contains teaching materials and plans for future space missions.

FIND THE RIGHT STUFF by pressing Spacelink's Hot Topic button. NASA provides images and the intended flight plans for Apollo 13 as well as a link to material about Universal Pictures' *APOLLO 13.*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STAGE ONE
APOLLO 13

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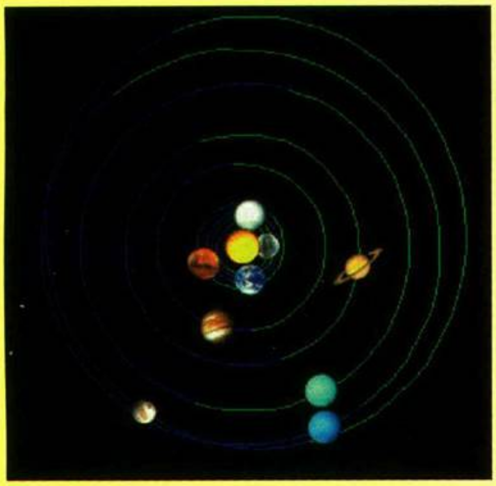

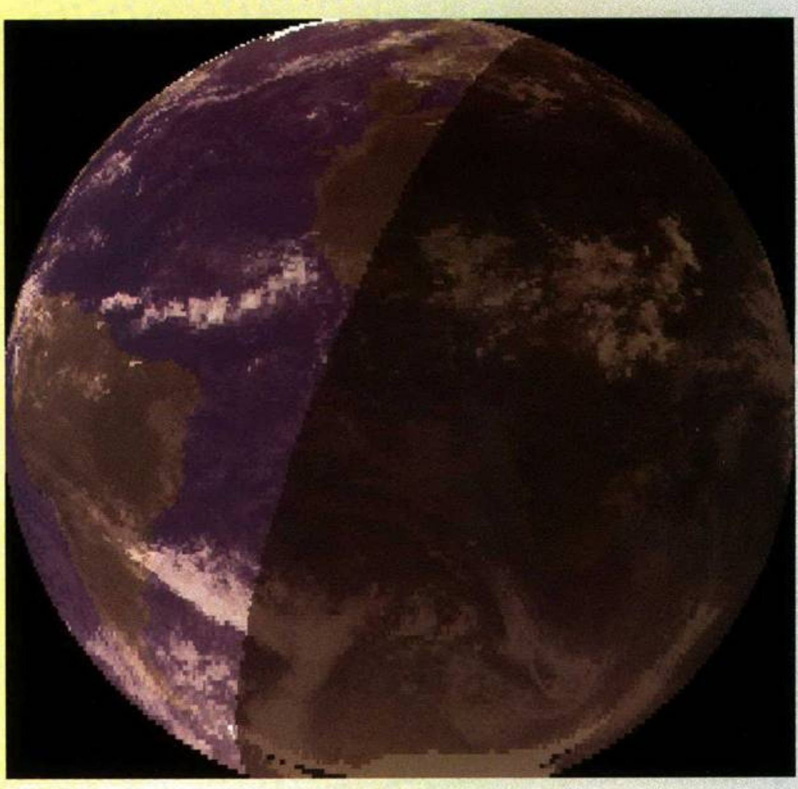

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newsletter are located on the Web at **http://maxwell.sfsu.edu/asp/tnl/tnl.html**.

The ASP also provides other educational support, much of which is not electronic but deserves mention. They have linked teachers and astronomers together in a program called Project ASTRO. Instead of arranging one-time visits, the program trains astronomers as long-term interactions as resource agents who work with students and teachers in and out of the classroom. For more information, e-mail Jessica Richter at jrichte@cello.gina.calstate.edu.

Educators also use the Internet to send and receive mailing lists. A mailing list administrator makes copies of a document and sends them to members of the mailing list. For example, the University of Nevada sponsors a list on teaching tips and lesson plans for K-12 science teachers. To subscribe, send an e-mail message to majordomo@unr.edu. Leave the subject line blank (enter a space if your mail program doesn't allow a blank line). For the text, type subscribe galileo and your-email-address (for example, subscribe galileo dbruning@astronomy.com).

Great images, such as those at **http://www.stsci.edu/EPA/Recent.html**, provide much of the spice and appeal of the Internet. Libraries at numerous schools don't contain many books about astronomy nor do they have current pictures of planets and galaxies. Not only does the Internet provide access to thousands of images, but users can print the images, explore some of them interactively, or download them to a computer for enhancement with image processing programs (*NIH Image* is freeware available from **http://wwwhost.ots.utexas.edu/mac/index-by-product.html**).

Not all of the exciting high-tech trends in astronomy education are happening on the Internet. NASA is creating new educational initiatives such as its NASA Classroom of the Future. This program is producing a multimedia package called the *Astronomy Village*. The software integrates library readings, software tools such as *NIH Image*, simulated telescopes, video and audio clips of lectures, and hands-on experiments to teach students what it's like to do astronomical research and how scientists work. The package will be available from NASA Teacher Resource centers; for a list indicating which Center serves your area, look at the Web location **http://nssdc.gsfc.nasa.ov/planetary/states03.html**.

Most of these electronic classroom activities are being developed by teachers, college professors, and professional astronomers. But they need your help.

Support your local school's efforts to get on the Internet. Many school administrators don't yet know about its power to provide information, imagery, and opportunity for students and teachers. If you're connected, offer to demonstrate the educational resources available to the principal and science teachers. A good place to start is "Using the Net in School" written for NASA's K-12 Internet Initiative and located at **http://quest.arc.nasa.gov/net-learning.html**. It has information about getting onto the Internet and what the Net has to offer educators.

And of course your skills as a backyard astronomer are always in demand at most schools. Take your scope to the local school and show the kids the Sun or the Moon during the day. Arrange for a nighttime star party. Help the kids make a scale model of the solar system or show them slides of your favorite deep-sky objects. Don't forget to let the kids ask questions.

Kids are eager to learn astronomy. All they need is a little encouragement and someone to show them the way. Their fascination with computers makes the Internet an ideal tool for harnessing their imagination and creativity. ☐

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7mm Nagler, 1¼" eyepiece, 82° field	$219
9mm Nagler, 82° field, 1¼" or 2"	$239
13mm Nagler, 82° field, 1¼" or 2"	$279
12mm Nagler, Type II, 82°, 1¼"/2"	$279
16mm Nagler, Type II, 82°, 1¼"/2"	$299
20mm Nagler, Type II, 82°, 2" only	$375
1¼" Paracorr Visual Coma Corrector	$159
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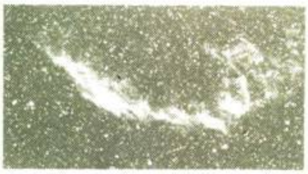
"From my light polluted backyard, the view ... was better with the O-III than with any other filter tested. The view was even better than without the filter from a dark-sky site." ***SKY & TELESCOPE*, July 1995**

SEE THE HORSEHEAD!

*"**LUMICON's H-Beta Filter** will show subtle features in emission nebulae that the others fail to reveal. It can't be beat for the elusive Horsehead and California nebulae. . ."* ***SKY & TELESCOPE*, July 1995**



"I CAN SEE THE VEIL NEBULA!"

Rich Zepernick saw the Veil Nebula for the very first time with a **LUMICON UHC Filter**. He stated, *"It was actually there! and not just around 52 Cygni, but the whole loop! Words cannot possibly express my feelings. I don't know how I managed without these filters."*
Rich Zepernick, Cresskill, NJ

DEEP-SKY FILTER™

BEST for Astrophotography!

"Stunning is all I can say," says noted astrophotographer Jack Newton. Great for BOTH color and black and white photography.

BEST WIDE-BAND FILTER!

*"Based on our tests we'd recommend a LUMICON Deep-Sky and Oxygen-III as complementary filters. The LUMICON Deep-Sky Filter clearly had the best contrast for **reflection** nebulae."* ***ASTRONOMY*, February 1991**

	Premium*
0.96" LUMICON DEEP-SKY Filter threads into most 0.96" eyepieces	$59.50
1¼" LUMICON DEEP-SKY Filter threads into most 1¼" eyepieces	$79.50
48mm LUMICON DEEP-SKY Filter (1.7" aperture), threads into most 2" eyepieces. Also fits LUMICON EASY-GUIDERS	$119.50
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2" Rear Cell Filter, fits SCT's Deep-Sky, **$119.50** UHC, O-III, H-Beta,	$199.50
1¼" LUMICON UHC Filter threads into most 1¼" eyepieces	$99.50
48mm LUMICON UHC Filter (1.75" aperture) fits most 2" eyepieces	$199.50
DEEP-SKY and choice of **UHC, O-III or H-BETA** Filter (**Save 11%**) 1¼" **$159.50**; 48mm	$279.50
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Oxygen-III Filter for very faint planetary and diffuse nebulae, 11nm bandpass at 496nm and 501nm O-III lines **1¼" $99.50, 48mm**	$199.50
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Universal adapter for 48mm or 2" filters. Allows use of any 1¼" eyepiece	$25.00

**Premium filters are currently the best in the world. All Lumicon filters include individually measured transmission data.*

DEEP-SKY ASTROPHOTOGRAPHY

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FILM HYPERSENSITIZATION KITS†

LUMICON HYPER-KITS™ yield 3-15x film speed gain in long exposures. They are safe & simple to use. Easy HYPER-KIT includes a chamber with all controls and fittings, thermometer, a refillable cylinder of non-flammable forming gas & hand-operated vacuum pump.

†U.S. Patent 4,473,636

MAKE YOUR OWN HYPERED FILM

MODEL 300 HYPER-KIT sensitizes any 35mm film in hours. Best for 2415. Achieves highest possible film speeds **$325**

MODEL 600 HYPER-KIT (See photo) Like the Model 300, but also sensitizes 120/220 larger format film and small glass plates **$395**

MODEL 1200 HYPER-KIT is for 4X5" plates and film up to 5X7". Has 2 gas cylinders and includes temperature controller **$595**

Temperature controller for any HYPER-KIT **$75**

Electric Vacuum Pump, Model R-10 **$325**

GUIDE OFF-AXIS FOR LOVELY ASTROPHOTOS

All **LUMICON EASY-GUIDER™** off-axis guiders† have both radial and 360° rotational adjustments for 5X easier guide-star selection, use 48mm filters, 360° camera rotation, large prisms for bright guide-stars. †U.S. Patent 4,448,500
Specify Camera and Telescope type.

NEWTONIAN EASY-GUIDER™

Full aperture. Installs in seconds. Specify 2" or 1¼".

NEWTONIAN EASY-GUIDER	**$189.50**
48mm Coma corrector/field flattener	**$285**
3X Relay Diagonal (see photo)	**$99.50**
Illuminated reticle eyepiece, pulsed	**$109.50**

Guider for Hasselblad **$409**, Mamiya 645 **$199**
Pentax 6X7 **add $119;** Pentax 645 **add $139**

CASSEGRAIN EASY-GUIDER™

For C-8, Meade 2080, Cynamax-8. Includes 50mm achromatic lens for f/5.8 operation—3X shorter exposures! **Superb rich field viewing, too!**

CASSEGRAIN EASY-GUIDER **$249.00**
Adapter for Hasselblad **$225,** Mamiya 645 **$98**
Pentax 6X7 **add $119;** Pentax 645 **add $139**

GIANT EASY-GUIDER™

For Celestron-11, C-14, and the 10" Meade 2120. Includes 80mm clear aperture achromatic lens for edge-to-edge illumination & pin-point star images. F-ratio adjustable f/4-f/11. **Also yields unmatched Rich-Field viewing.**

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Adapter for Hasselblad **$295,** Mamiya 645**$149**
Pentax 6X7 **add $129;** Pentax 645 **add $149**

WHAT DO YOU NEED?

1. Illuminated reticle eyepiece **$109.50**
Lumicon 12mm eyepiece system has adjustable LED illumination, dual crosslines, battery pack.

2. Cable release for long exposures **$9.95**

3. **LUMICON Digital Drive Corrector . $249**
Dual-axis drive corrector is essential for astrophotography and/or field use of your telescope. 30Hz/90Hz variable output controls telescope drive. 60Hz digital reference ±12VDC Declination control output. Both 110VAC and 12VDC input for home or field use. Dec. reverse switch for Newtonians.

Declination motor (state telescope)	**$109**
Variable dec. speed drive w/built-in 5AH battery	**$299**

HYPERSENSITIZED FILM

SR1600
Scotch
1000

NEW **SRV3200**

YES! WE STILL HAVE FUJI HG400!

LUMICON Hypersensitized film is essential for good deep-sky astrophotography. Deduct 10% for 3 or more rolls (mixed o.k.). ***No C.O.D.s.***

Film Type, 35mm	Exposures	Price
2415, Ultra-fine B&W, red sens.	36	**$11.95**
SR-G3200, fastest of all, color neg	24	**$14.95**
Kodak Ektar 1000 fast, fine grain	24	**$12.95**
Fuji HG400 fine grain color neg.	12	**$14.95**
Ektachrome 1600, fast slide film	24	**$14.95**
Fujichrome RD100, fine grain slide	24	**$12.95**
D-19 B&W Developer	1 gal.	**$6.95**

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LUMICON LUMILITE™ Red LED Flashlight

This red LED flashlight preserves night vision. It uses 2 AA cells (included!) which last 60-100 hours.

LUMILITE red LED flashlight	**$14.95**

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LUMICON
UNITRAK

LUMICON UNITRAK DRIVE CORRECTOR

Operate your telescopes ***anywhere!*** Use the single-axis Unitrak with a 12V DC car battery. The dual-axis drives are for photography and use either 12V DC or 125V AC.

Unitrak™ single-axis corrector	**$99.95**
LUMICON DX200 dual-axis correc.	**$249.00**
DX2BP incl. battery & charger	**$298.00**
Convenient rechargeable Porta-Pac battery:	
12V DC Porta-Pac (5AH) & recharger	**$79.50**
12V DC Porta-Pac (12AH) & recharger	**$99.50**

48MM COLORED FILTERS

FOR EVERY NEED

Select 48mm UV, Red, Yellow, Green (ea.)	**$19.95**
48mm Cyan (absorbs red)	**$69.00**
48mm High Performance Blue (95% T)	**$49.00**
48mm Tri-Color Blue (80% T- 400nm)	**$49.00**
48mm Ultraviolet (85% T- 370nm)	**$49.00**
Color Separation Set: cyan, red, yellow, blue	**$149**

RICH FIELD! 2° in 8'' SCT

NOW ONLY
$99.50

LUMICON Rich-Field Viewer on C-8 with LUMICON 2'' star diagonal and 2'' eyepiece.

The LUMICON Rich-Field Viewer fits **all** commercial Schmidt-Cassegrain telescopes. It has a high-performance coated achromatic focal reducing lens with 50mm or 80mm clear aperture for **totally unvignetted viewing** with 2'' or 1¼'' eyepieces. It is available in several combinations depending on the eyepiece and field-of-view you desire (see chart below).

LUMICON Rich-Field Viewer	**$99.50**
Giant Rich-Field Viewer (10-14'')	**$250.00**

Optional Eyepiece	**TRUE FIELD**	**Price**
Meade 32mm Plossl	1.4°	**add $99**
Meade 32mm 2'' Wide-Field†	1.9°	**add $439**
Meade 40mm 2'' Wide-Field†	2.4°	**add $498**

†Includes 2'' enhanced aluminum Star Diagonal (may not reach focus on some telescopes).

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Protect your valuable telescope optics, eyepieces and accessories with these black vinyl covers. Add $1 shipping. Deduct 10%, 2 or more sets.

1¼'' O.D. plug, seals focuser	**4/$2**		
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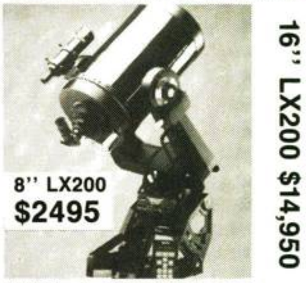
1¼'', 1⅜''	**3/$2**	7½''	**$10**
1½''	**2/$2**	9½'', 10.4''*	**$15**
2''	**2/$2**	12½'', 12⅞''*	**$20**
2⅛''	**2/$20**	15.6'', 16''*	**$28**
5½''	**$6**	19'' (DS-16)	**$35**
*Fits Odyssey		21'' (Odyssey-II)	**$35**

MEADE 8'' - 16'' LX200 SCHMIDT-CASSEGRAINS



NEW Meade 8'' LX200 Telescopes

LX100 - includes wedge, best for photography.
LX200 - full computer control w/64K obj. mem.
NOTE: A wedge is **not** needed for visual observing with the LX200 Drive. Select f/10 or f/6.3 (no extra charge) for your Schmidt-Cassegrain.

8'' LX100 with wedge ($105 P&S)	**$2095**
8'' LX200 w/computer ($105 P&S)	**$2495**
Wedge for photographing w/8'' LX200	**$139**
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10''	**$129**;
12''	**$189**;
16''	**$289**

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Meade 2045D 4'' f/10 w/motor ($40 P&S)	**$699**
Meade 2080B 8'' f/10 w/tripod, wedge, MCOG ($95 P&S)	**$1249**
Model 2120B 10'' f/10 w/wedge, tripod, MCOG ($125 P&S)	**$1599**

PHOTOGRAPHY ACCESSORIES

Cassegrain EASY-GUIDER 4'', 8'', f/6 or f/10	**$249**
Giant EASY-GUIDER for 10''/12'' f/4-f/10	**$395**

MEADE STARFINDERS

8'' f/6
$699*

New 8'' f/6 Meade Starfinder telescopes

See the Meade ad in this magazine for full descriptions. These are complete telescope systems with motor drive (equat. only), mount, finderscope and 25mm (=48X) eyepiece.

6'' f/8 Dobsonian Starfinder ($46 P&S)	**$325**
6'' f/8 Equat. Starfinder 6(add $79 P&S)	**$599**
8'' f/6 Dobsonian Starfinder (add $59 P&S)	**$425**
8'' f/6 Equat. Starfinder 8 (add $89 P&S)	**$699**
10'' f/4.5 Dobsonian Starfinder ($85 P&S)	**$595**
10'' f/4.5 Equat. Starfinder 10 (add $99 P&S)	**$799**
12.5'' f/4.8 Dobsonian Starfinder ($95 P&S)	**$795**
16'' f/4.5 Starfinder 16 (ship. freight COD)	**$2495**

*All Starfinder telescopes shipped directly from Meade to the purchaser. Please add the indicated packing & shipping charge to the price. Slightly lower P&S for payment by check. LUMICON showroom prices are $99 higher.

ACCESSORIES

LUMICON carries all Meade accessories.

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LUMICON DX200 Dual-axis drive cor.	**$249**
Meade 47M Dual-axis drive corrector with tangent arm & electric declination	**$475**
LUMICON DX2BP Dual-axis drive corrector with built-in battery pack	**$299**

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Higher Performance — Lower Price

LOW PRICE—from $399

LUMICON SKY VECTOR FEATURES:

- "GUIDE" mode leads you to object
- Digital right ascension readout to 1 min.
- Digital decl. readout to 10 arc-min.
- 4000 pulse (0.09° accuracy) encoders
- Polar alignment ***not required!***
- Motor drive ***not required!***
- Just sight two stars to align!
- Works **equally well** for alt-azimuth telescopes like Coulter Odyssey and equatorial mounts like C-8, Meade 2080.
- **No need** to enter latitude, longitude, etc.

SKY VECTOR I™ $399

NEW! With over 220 object memory including the 110 Messier and 58 best NGC objects.

SKY VECTOR II™ $499

IMPROVED — Planets, Over 3,700 Objects! With size, magnitude and full visual description.

NGC SKY VECTOR™ $699

IMPROVED!—5500 Additions / Corrections

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Improved NGC SKY VECTOR with over 12,000 object memory including the planets, complete, corrected RNGC catalogue, IC catalogue, P&K planetary catalogue, & much more!

Specify Telescope Type: Meade 2045, 2080, 2120, C-8, C-11, Odyssey 8, 10, 13, 17½, Alt-Azimuth.

Ultima 8, 11 .. **add $25**, C-14 .. **add $75**

COMA CORRECTOR

Coma 1 inch off-axis 17½'' f/4.5

Same field with LUMICON coma corrector; smaller, more numerous stars.

This computer-designed LUMICON 2'' lens reduces coma and flattens the field for both viewing and photography. **It threads into LUMICON 2'' EASY-GUIDERS for effortless installation.** This zero power lens does not change image scale nor shift focus, and all lens surfaces are multi-coated for highest efficiency. Clear aperture = 1.8''.

LUMICON 48mm Coma Corrector/Field Flattener Lens	**$285.00**
LUMICON 2'' EASY-GUIDER	**$189.50**
2'' EASY-GUIDER (Mamiya 645)	**$239.50**
2'' Adapter for Pentax 6X7	**$129.00**
2'' Adapter for Hasselblad	**$229.00**
2'' Adapter for Bronica SQ-A	**$175.00**
2'' Extension for viewing	**$26.00**

2'' DELUXE BARLOW

1.8x Multiplier Lens (2'' Barlow)

LUMICON 1.8x Multiplier Lens (2'' Barlow)	**$259.00**

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LARGE UV/DUST SEAL

Protect the optics of your 8-14'' Schmidt-Cassegrain with a UV/Dust Seal. Simply thread it onto the rear cell, then attach all normal accessories. The large size fits Meade 2120, Celestron-11 and -14 & has a high quality multi coated (removable) 72mm UV filter.

Deep-Sky Filter/Dust Seal for C-8, 2080	**$119.50**
UV/Dust Deal for Celestron C-8	**$39.00**
UV/Dust Seal for Meade 2080, 2045	**$39.00**
UV/Dust Seal (large) for Meade 2120	**$89.50**
UV/Dust Seal for Celestron-11, -14	**$89.50**

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New! Thread-on for Odyssey

FROM $69.50

LUMICON® LOW PROFILE FOCUSERS

LUMICON now offers 3 different low-profile helical focusers. They stand only 1¼-1½'' above the telescope tube. Use the 1¼'' or 2'' versions for viewing. Use the 2'' non-rotating focuser for convenient photography with the LUMICON 2'' EASY-GUIDER™.

Select your desired base-plate shape!
Coulter Odyssey (thread-on installation), Flat, 7'' OD, 9½'' OD, 12½'' OD, 16'' OD, 21'' OD.

LUMICON 1¼'' Helical Focuser	**$69.50**
LUMICON 2'' Helical Focuser 1½'' high	**$75.00**
LUMICON Non-rotating Helical Focuser	**$129.00**
2'' Astro Systems focuser, only 2'' high	**$139.00**
3 handles for non-rotating focuser	**$12.95**
2''/1¼'' **adapter** w/48mm filter threads	**$20.00**
2'' LUMICON EASY-GUIDER	**$169.50**

LUMICON 50mm, 80mm SUPER-FINDER™

Visual Astronomers prefer the LUMICON 80mm SUPER-FINDER™, since hundreds of deep-sky objects, including most Messier objects, are visible directly. SUPER-FINDERS also make nice small portable telescopes. 80mm aperture, F=300mm coated achromat or 50mm, F=200mm coated achromat. Eyepieces and/or star diagonal are extra.

1¼'' 50mm Finderscope **$69.50**, right-angle	**$69.50**
1¼'' straight-thru 80mm SUPER-FINDER	**$189.50**
1¼'' right-angle 80mm SUPER-FINDER	**$199.50**
1¼'' right-angle version, w/star diagonal	**$239.50**
25mm Cross-hair 1¼'' eyepiece (12X)	**$49.00**
Large mounting rings for 80mm Finder	**$55.00**
1¼'' Star Diagonal **$49**, Mounting Brackets,	**$39.50**
1¼'' 45° diagonal for correct left-right views	**$59.50**

LOTS OF ADAPTERS

2'' adapter for C-8, Meade 2080, etc.	**$29.50**
2'' adapter for C-80, C-100 refractor	**$39.50**
2'' adapter for C-70, C-80F, C-100F fluorite	**$39.50**
2'' adapter for C-6, Comet Catcher, Meade 312	**$30.00**

EXTENSION TUBES

1'' long 1¼'' OD thread-in extension	**12.00**
2½'' long extension (holds 1¼'' filters)	**19.50**
4½'' long extension for 1¼'' eyepieces	**$25.00**
3'' long extension for 2'' eyepieces*	**$29.00**
2'' long extension for 2'' eyepieces*	**$29.00**

VIEWING ADAPTERS

2''/1¼'' reducing bushing, threaded 48mm*	**$25.00**
2''/T-thread adapter, threaded 48mm*	**$25.00**
T-thread/1¼'' adapter	**$25.00**
F/10 2'' or 1¼'' eyepiece viewing adapter for Giant Easy-Guider	**$39.50**
Low profile star diagonal eyepiece holder	**$16.00**
Meade 2'' Diagonal/Giant Easy-Guider	**$39.50**

**Threaded to hold 48mm filters.*

SKY ALMANAC

October's Orionids, perhaps the best meteor shower of 1995, highlight a month that features three bright planets in the evening sky and Mercury at its best before dawn.

by Deborah Byrd

Highlights
by Rick Shaffer

Date Event
8 Shadow on the Hunter's Moon . . . *(p. 63)*
22 Hunting the Hunter's Meteors . . . . . *(p. 61)*
24 Solar Eclipse over Asia. . . . . *(p. 61)*
All month:
Venus Returns to the Evening Sky . . *(p. 56)*
Comet d'Arrest Skirts Sculptor Galaxies . . . . . *(p. 63)*
First Views:
Mercury at Its Morning Best. . . . . . *(p. 64)*
A Whale of a Show by Hebe . . . . *(p. 64)*
Observer's Challenge:
Hide and Seek Among Saturn's Satellites. . . . . *(p. 65)*

The Starry Sky:
Pisces. . . . . . . *(p. 62)*

Walk outside on any crisp, clear autumn evening and rain will probably be the furthest thing from your mind. Yet at this time of year, the sky you are viewing is populated by imaginary water creatures — inhabitants of the sky's ocean that have been seen by stargazers for thousands of years. It's a relatively small area of the celestial sphere, visible at a glance if you look southward in the evening from the Northern Hemisphere.

This part of the sky is sometimes called "the ocean in the autumn sky." It contains a few well-known fish, graceful Pisces and its southern counterpart Piscis Austrinus, a whale (Cetus), a sea goat (Capricornus), and a water carrier (Aquarius). The mighty river of the heavens, Eridanus, flows nearby. Perhaps, in the minds of some ancient stargazers, Eridanus emptied its waters into the sky sea.

Why this association between water and autumn? When these constellations were identified and named more than 2,000 years ago, the Sun passed through this part of the sky during the rainy season.

These stars and their constellations tend to be fairly dim. The most noticeable star here is Fomalhaut, in the constellation Piscis Austrinus the Southern Fish. Fomalhaut is sometimes called the Lonely One or the Solitary One because it shines brightly, at magnitude 1.2, in a star-poor region of the sky. It has also been called the Autumn Star.

Fomalhaut lies within a lopsided asterism of four stars in Piscis Austrinus. One of my favorite things to see in a dark sky is the zigzag line of stars extending from neighboring Aquarius toward Piscis Austrinus. Imagination transforms this jagged line into liquid sloshed from the Water Jar asterism of Aquarius into the open mouth of the Southern Fish.

The watery constellations play host to one of the October sky's more distinctive features, the Hunter's Moon. This Moon — the first Full Moon following the Harvest Moon — usually occurs in October. Only when the Harvest Moon, the Full Moon nearest the September equinox, falls in early October does the Hunter's Moon get pushed into November.

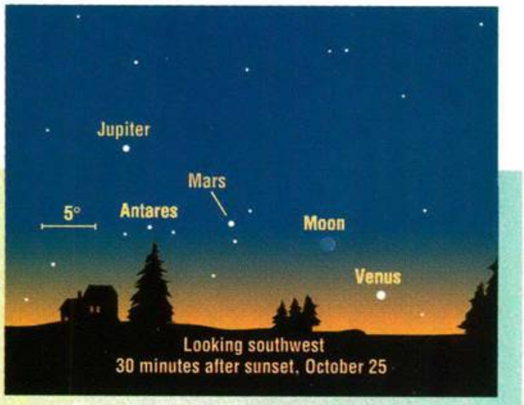
Both the Harvest and Hunter's Moon are special because, as seen from the Northern Hemisphere, the ecliptic — the path of the Sun, Moon, and planets across the sky — makes a shallow angle relative to the western evening horizon at this time of year. As a result, less time than normal elapses

Venus Returns to the Evening Sky

After having been lost in the Sun's glare for more than two months, Venus returns to the evening sky in early October. It isn't easy to spot at first, setting just 30 minutes after the Sun does on the 1st. But with each passing day it creeps a little higher in the sky and by the 31st sets nearly an hour after the Sun.

The reason Venus clings to the horizon for so long during this evening apparition is that as seen from the Northern Hemisphere in autumn, the ecliptic makes a very shallow angle with the western horizon after sunset. Thus Venus' angular separation from the Sun doesn't translate into much altitude. By early 1996, the ecliptic will make a much steeper angle with the western horizon and Venus will dominate the western sky after sunset.

This month's return of Venus signals another event of even more interest: a grand conjunction of Venus, Mars, and Jupiter during November. You can get a taste for the upcoming action by watching the three planets pull closer to one another during the course of October. On the 1st, while Venus hugs the western horizon just after sunset, Mars lies 25° to the upper left of Venus and Jupiter another 25° to the upper left of Mars. (Although even Jupiter lies only 20° above the horizon 30 minutes after sunset.)



Looking southwest
30 minutes after sunset, October 25

As the month progresses, Venus rises up to greet the other planets while Mars and Jupiter sink. Because Jupiter sinks faster than Mars, however, the net effect is that the three move closer together. By the 31st, all lie within 20° of one other. Probably the nicest views this month come on the 25th and 26th, when the waxing crescent Moon passes the trio. — *Rick Shaffer*

1995

OCTOBER

1 First Quarter Moon is at 10:36 a.m. EDT

2 The Moon passes 5° north of Neptune, 1 p.m. EDT
The Moon passes 6° north of Uranus, 8 p.m. EDT

4 Venus passes 3° north of Spica, 5 a.m. EDT
Mercury is in inferior conjunction, 9 p.m. EDT

6 The Moon passes 6° north of Saturn, 6 p.m. EDT

8 Full Moon is at 11:52 a.m. EDT; penumbral lunar eclipse (page 63)

9 Asteroid Ceres is in conjunction with the Sun

14 The Moon is at apogee (251,408 miles from Earth), 10:06 p.m. EDT

16 Last Quarter Moon is at 12:26 p.m. EDT

18 Asteroid Hebe is at opposition (page 64)

20 Mercury is at greatest western elongation (18°), 10 a.m. EDT (page 64)

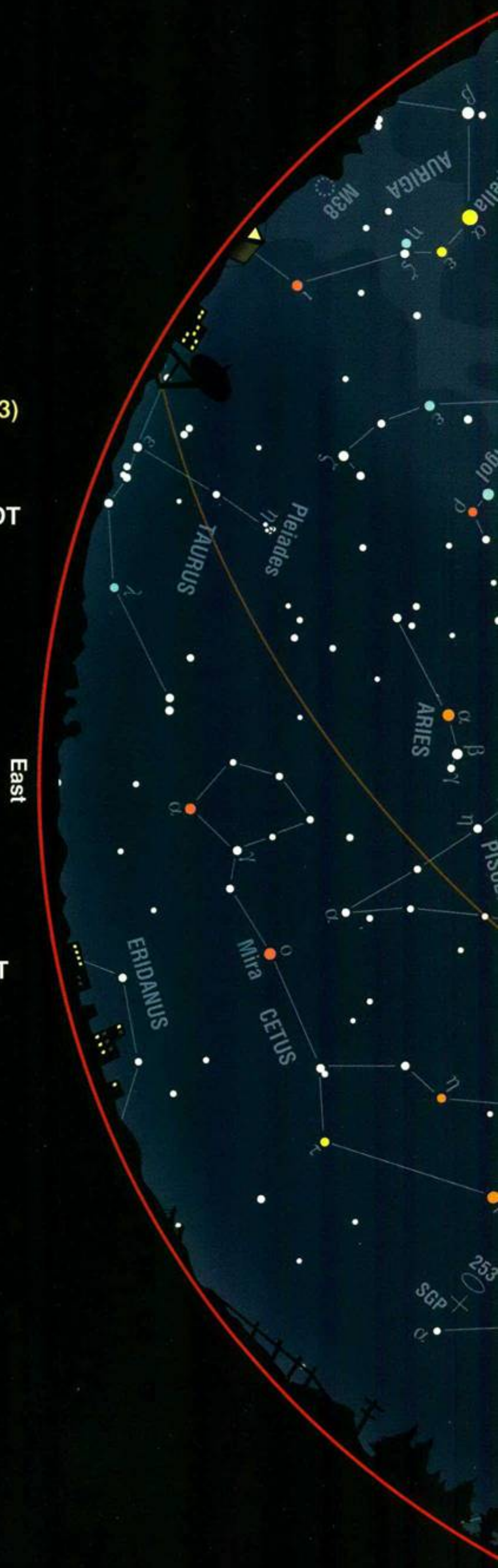
22 Orionid meteor shower peaks (page 61)
The Moon passes 4° south of Mercury, 6 p.m. EDT

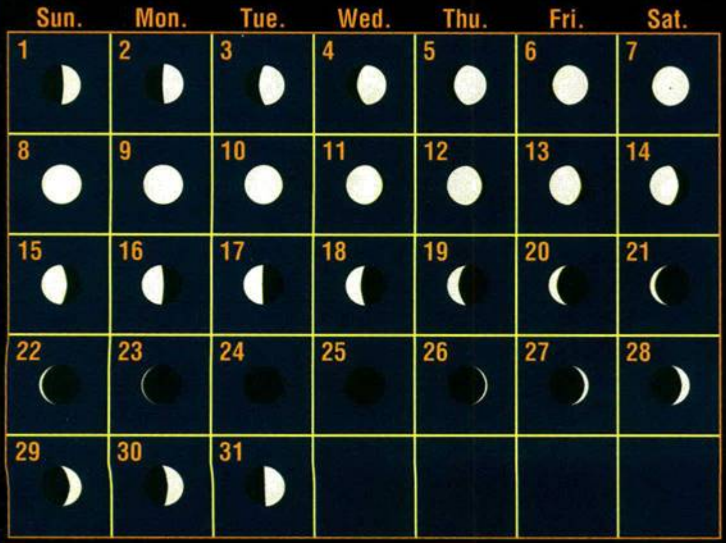
24 New Moon is at 12:36 a.m. EDT; total solar eclipse (page 61)

25 The Moon passes 1.9° north of Venus, 7 a.m. EDT

26 The Moon passes 4° north of Mars, 7 a.m. EDT
The Moon is at perigee (226,671 miles from Earth), 5:02 p.m. EDT

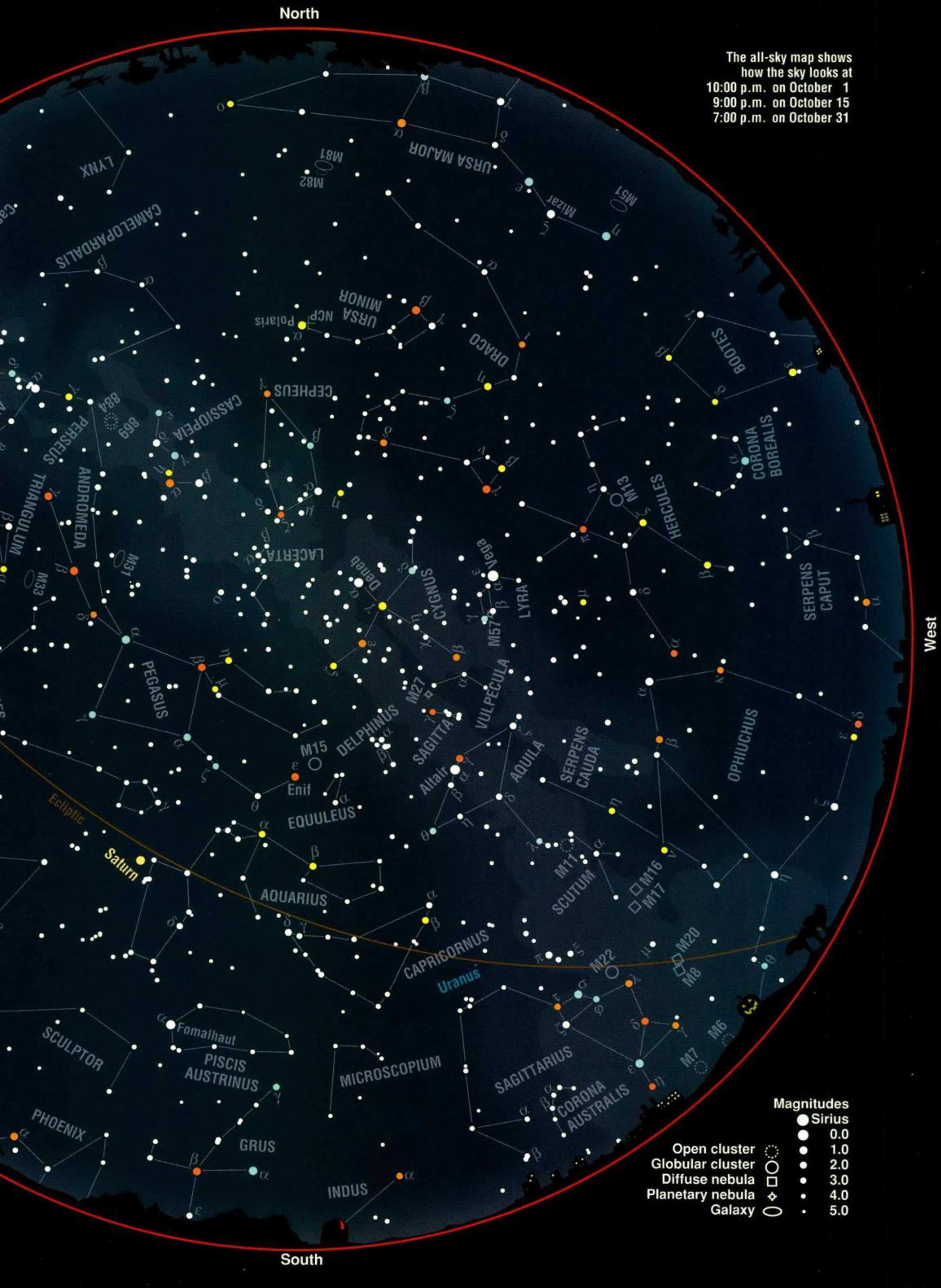
27 The Moon passes 4° north of Jupiter, 2 a.m. EDT



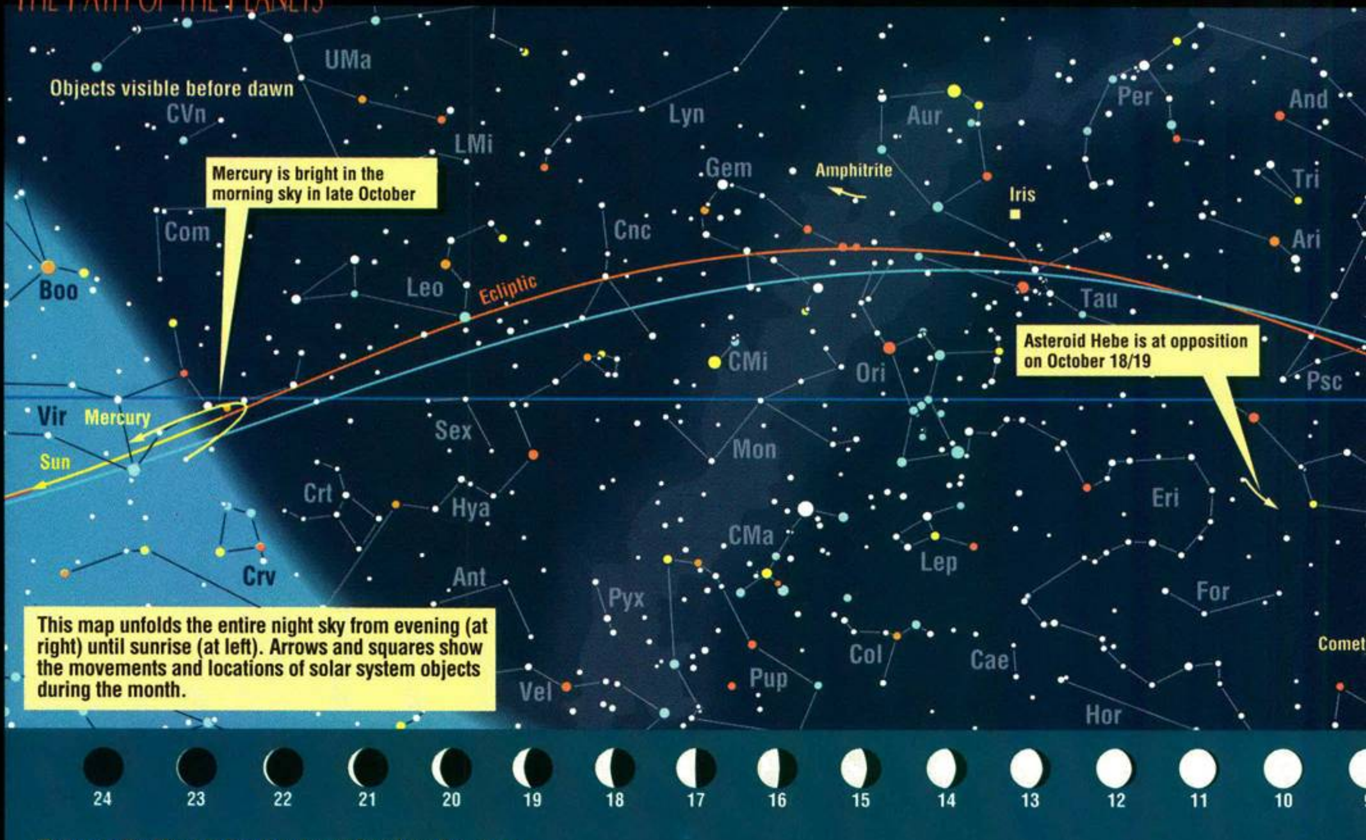


Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

The all-sky map shows
how the sky looks at
10:00 p.m. on October 1
9:00 p.m. on October 15
7:00 p.m. on October 31


North
South
West
LYNX
M81
M82
URSA MAJOR
Mizar
M51
CAMELOPARDALIS
URSA MINOR
NCP
Polaris
DRACO
BOOTES
CEPHEUS
CASSIOPEIA
884
869
PERSEUS
TRIANGULUM
ANDROMEDA
M31
M33
LACERTA
Deneb
CYGNUS
Vega
LYRA
M57
M13
HERCULES
CORONA BOREALIS
SERPENS CAPUT
PEGASUS
VULPECULA
M27
SAGITTA
DELPHINUS
M15
Enif
EQUULEUS
Altair
AQUILA
SERPENS CAUDA
OPHIUCHUS
Ecliptic
Saturn
AQUARIUS
M11
SCUTUM
M16
M17
M20
M8
M22
CAPRICORNUS
Uranus
SCULPTOR
Fomalhaut
PISCIS AUSTRINUS
MICROSCOPIUM
SAGITTARIUS
M6
M7
CORONA AUSTRALIS
PHOENIX
GRUS
INDUS
Magnitudes
Sirius
0.0
1.0
2.0
3.0
4.0
5.0
Open cluster
Globular cluster
Diffuse nebula
Planetary nebula
Galaxy

THE PATH OF THE PLANETS


Objects visible before dawn
UMa
CVn
LMi
Lyn
Aur
Per
And
Com
Gem
Amphitrite
Iris
Tri
Ari
Boo
Leo
Ecliptic
Cnc
Tau
CMi
Ori
Psc
Vir
Mercury
Sun
Sex
Mon
Eri
Crt
Hya
CMa
Lep
Crv
Ant
Pyx
For
Col
Cae
Pup
Vel
Hor
Comet
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10

Mercury is bright in the morning sky in late October

Asteroid Hebe is at opposition on October 18/19

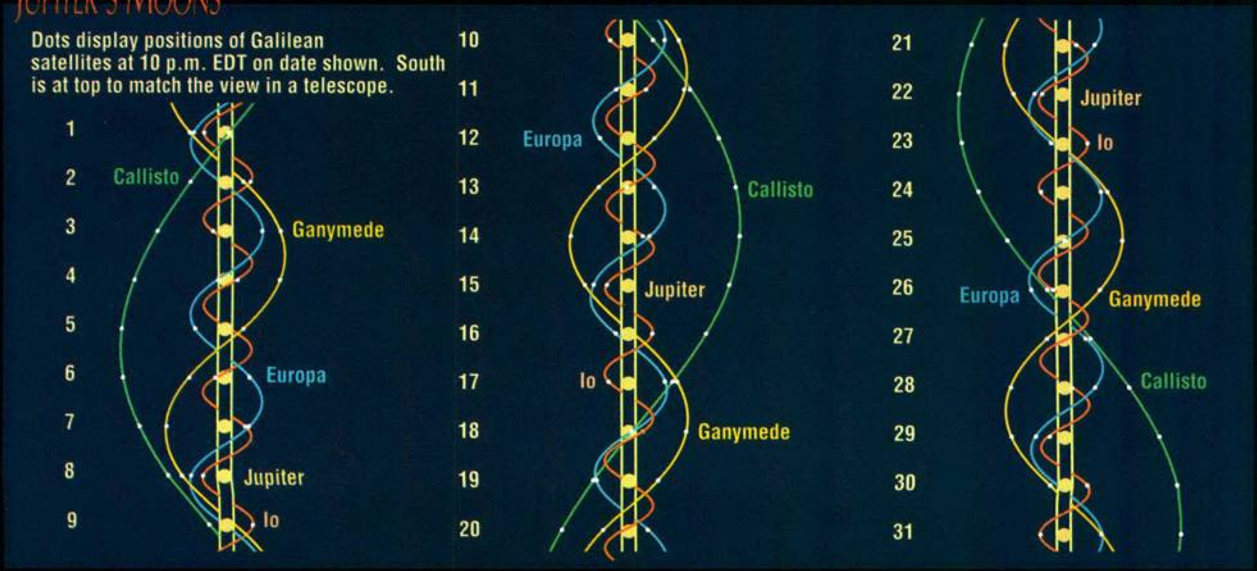
This map unfolds the entire night sky from evening (at right) until sunrise (at left). Arrows and squares show the movements and locations of solar system objects during the month.

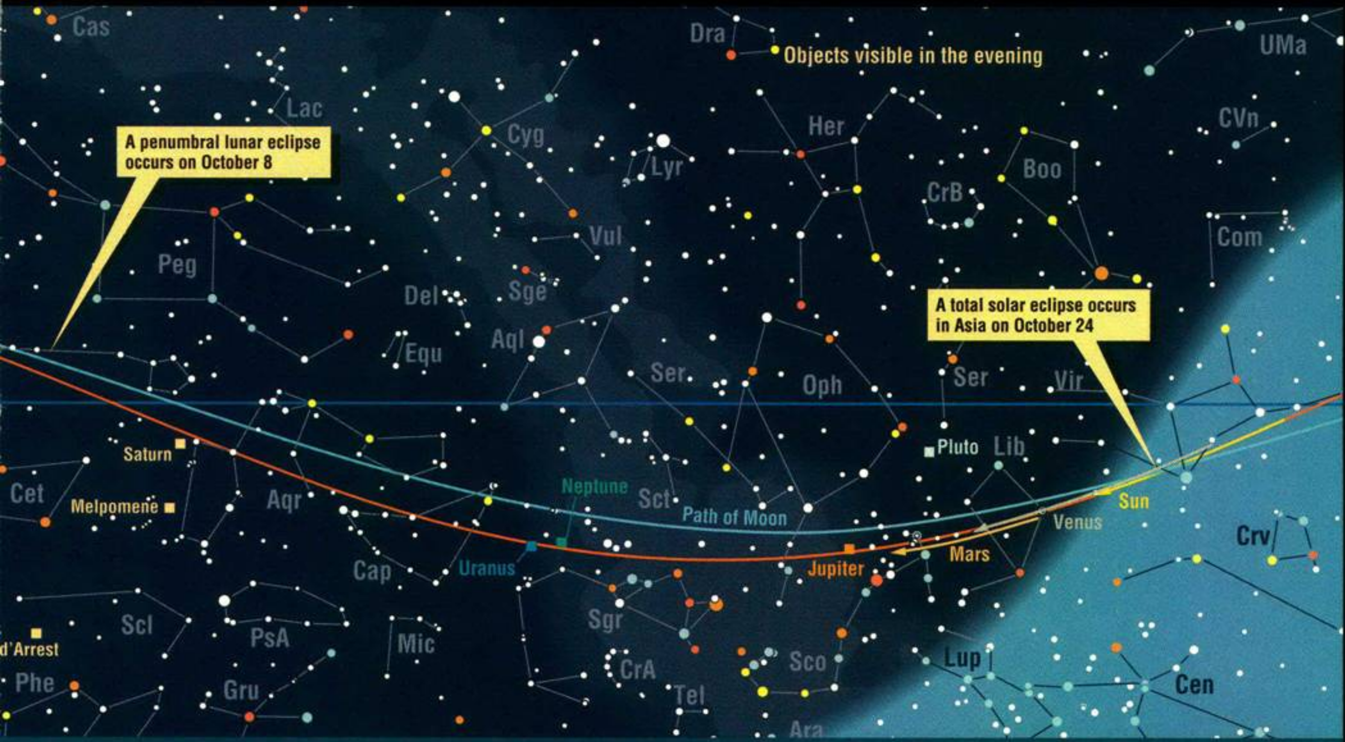
To locate the Moon in the sky, draw a line from the phase shown for the day straight up to the curved light-blue line.

PLANETS	MERCURY	MERCURY	VENUS	MARS	JUPITER
Date	October 15	October 31	October 15	October 15	October 1
Magnitude	0.5	–0.9	–3.9	1.4	–1.9
Angular Size	8.2"	5.5"	10.2"	4.3"	33.7"
Illumination	28%	87%	97%	96%	99%
Distance (AU) from Earth	0.823	1.228	1.644	2.188	5.857
Distance (AU) from Sun	0.308	0.362	0.725	1.481	5.296
Right Ascension (2000.0)	12h20.4m	13h28.0m	14h15.0m	15h33.6m	16h45.8
Declination (2000.0)	–1°11'	–7°10'	–12°59'	–19°49	–21°57'

JUPITER'S MOONS

Dots display positions of Galilean satellites at 10 p.m. EDT on date shown. South is at top to match the view in a telescope.

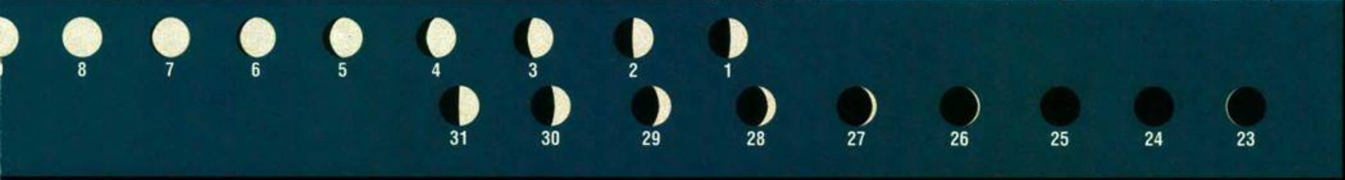



Cas
Lac
Dra
UMa
Cyg
Lyr
Her
CVn
Boo
CrB
Peg
Vul
Com
Sge
Del
Equ
Aql
Ser
Oph
Ser
Vir
Saturn
Pluto
Lib
Cet
Melpomene
Aqr
Neptune
Sct
Path of Moon
Sun
Venus
Crv
Mars
Jupiter
Cap
Uranus
Scl
PsA
Mic
Sgr
d'Arrest
Phe
Gru
CrA
Sco
Tel
Lup
Cen
Ara

Objects visible in the evening

A penumbral lunar eclipse occurs on October 8

A total solar eclipse occurs in Asia on October 24


8
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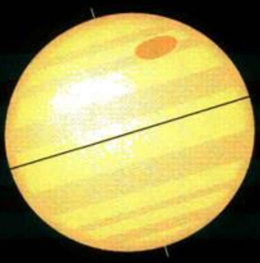
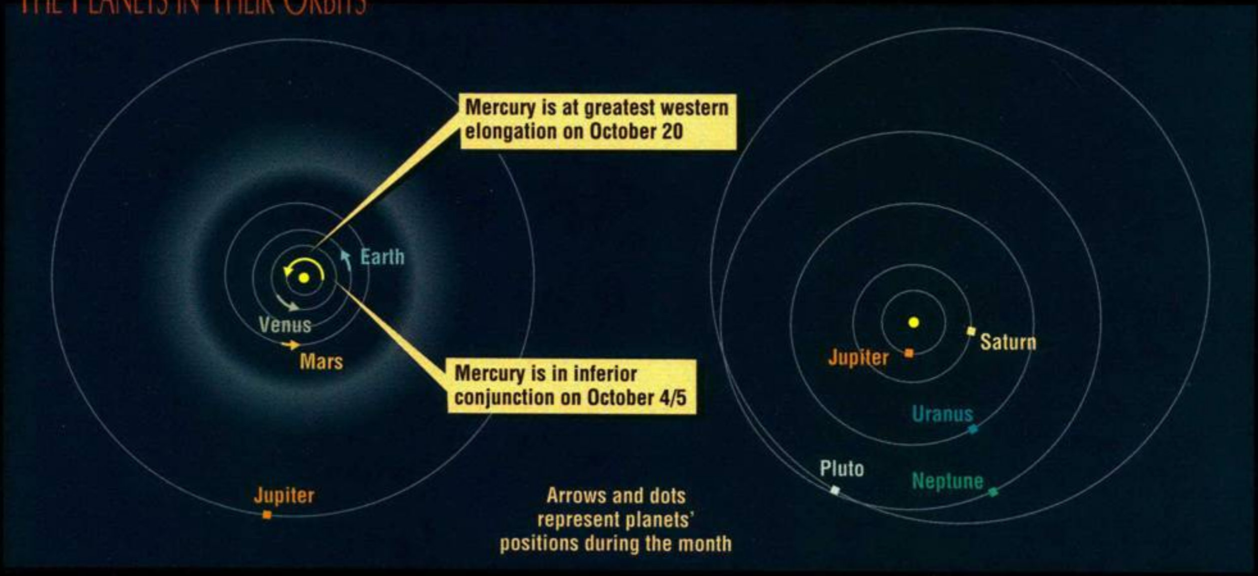


SATURN	URANUS	NEPTUNE	PLUTO
October 15	October 15	October 15	October 15
0.8	5.8	7.9	13.8
19.0"	3.6"	2.3"	0.1"
100%	100%	100%	100%
8.740	19.616	30.122	30.623
9.600	19.735	30.167	29.862
23h24.1m	19h55.0m	19h38.3m	15h58.7m
−6°24'	−21°23'	−20°59'	−7°17'

THE PLANETS IN THEIR ORBITS


Earth
Venus
Mars
Jupiter
Jupiter
Saturn
Uranus
Pluto
Neptune

Mercury is at greatest western elongation on October 20

Mercury is in inferior conjunction on October 4/5

Arrows and dots represent planets' positions during the month between moonrises on successive evenings, so the early evening sky is graced by the nearly Full Moon for several days in a row.

Moreover, around the time of the Harvest and Hunter's Moon, the Moon rises much farther north along the eastern horizon each evening. Watch for all these effects around this month's Full Moon on October 8. And keep your eyes focused on the Moon that night for the subtle shading of a penumbral lunar eclipse (see page 63 for details).

Although the narrow angle of the ecliptic helps in watching the Full Moon, it hinders viewing any planets not far from the Sun in the evening twilight sky. But don't turn your back on this region, because something wonderful is about to happen. First off, **Venus** returns to the evening sky. It starts the month exceedingly low in the west after sunset. In fact, if it weren't so brilliant (shining at magnitude –3.9), you wouldn't be able to see it so low in the sky.

When will you first spot Venus emerging from the twilight glare? That's hard to say. It depends somewhat on your latitude, with southerly observers favored slightly, but it depends more on your local sky conditions. If your western horizon tends to be blanketed in haze or mist during the evening hours, you will have to wait longer to see Venus than if you live under a pure desert sky. The planet remains low all month, and unless you look carefully, you might not see it at all. Try to glimpse it a little below and to the right of the very young Moon on the evening of October 25.

Perched somewhat higher in the west after sunset is the Red Planet, **Mars**. Although it isn't particularly bright at magnitude 1.4, you can notice it because of its reddish color and the steadiness of its light.

Mars lies among the background stars of Libra as October begins. After midmonth it moves into Scorpius and aims for an interesting part of that constellation, a little arc

Hunting the Hunter's Meteors

Seth Horowitz

The last half of October is the season of the Orionid meteor shower, so named because the meteors seem to radiate from a point just east of Orion's club. The source of the shower is an old favorite, Halley's Comet, which has been spreading dust and pea gravel along its orbit for thousands of years. Every year around October 22, Earth crosses Halley's orbit and friction with the atmosphere causes that dust and gravel to burn up, creating the meteor shower.

Although the Orionids normally rank as the third-best shower of the year, circumstances in 1995 may put the Orionids at the top of the heap. The two major meteor showers — the August Perseids and the December Geminids — both contend with bright moonlight this year. The Orionids peak just two days before New Moon, so there'll be no extraneous light to wash the fainter meteors from view.

Expect to see roughly 25 meteors per hour at the shower's peak on the morning of the 22nd. For more on observing the meteor shower, turn to "See the Orionids" on page 66. — *R.S.*

Solar Eclipse over Asia

Nelson Falsarella and Fatima Carnicel

The Moon's shadow touches Earth on October 24, bringing darkness to the daytime sky for observers across a thin swath of southern Asia and a partial eclipse to most everyone in Asia and northern Australia. Although it is a fairly short eclipse, with the Moon completely covering the Sun for just over two minutes at maximum, weather prospects are good in many of the areas.

Perhaps the best sites will be in India, where totality lasts up to a minute and a half and the weather at this time of year is typically clear and dry. If you travel to India, or any of the other countries in the eclipse track for that matter, you'll likely find that many local residents know little about astronomy but want to know a lot. Try to take some time from your schedule to show the locals the sky through your telescope. When I've done that, I've always gotten back much more than I've given.

I've seen four total eclipses and a few seconds of a fifth, and have found that 10- to 16-power binoculars provide the best views of the corona. For viewing prominences, try a small portable telescope at 25- to 60-power. Whatever you do, don't get so involved in photographing the eclipsed Sun that you forget to view it with your own eyes. For an overview of the eclipse, refer to "Off to See October's Eclipse" in the July 1995 issue. You can find details on photographing this or any other solar eclipse in "Shoot the Solar Eclipse" on page 80. — *R.S.*

of three stars known as the "crown of the scorpion." It sweeps through this grouping around October 25. Mars also appears near the waxing crescent Moon on the 25th and 26th, as seen from North America.

As October ends, Mars officially resides in Ophiuchus, although it lies near its old rival, the 1st-magnitude star Antares in Scorpius. (The name Antares comes from a Greek phrase meaning "rival of Ares," the Greek name for the Roman god Mars, because the star has a similar ruddy hue.) Mars now lies on the far side of the solar system from Earth, so through a telescope it appears as a tiny, bland disk measuring only 4.3" across.

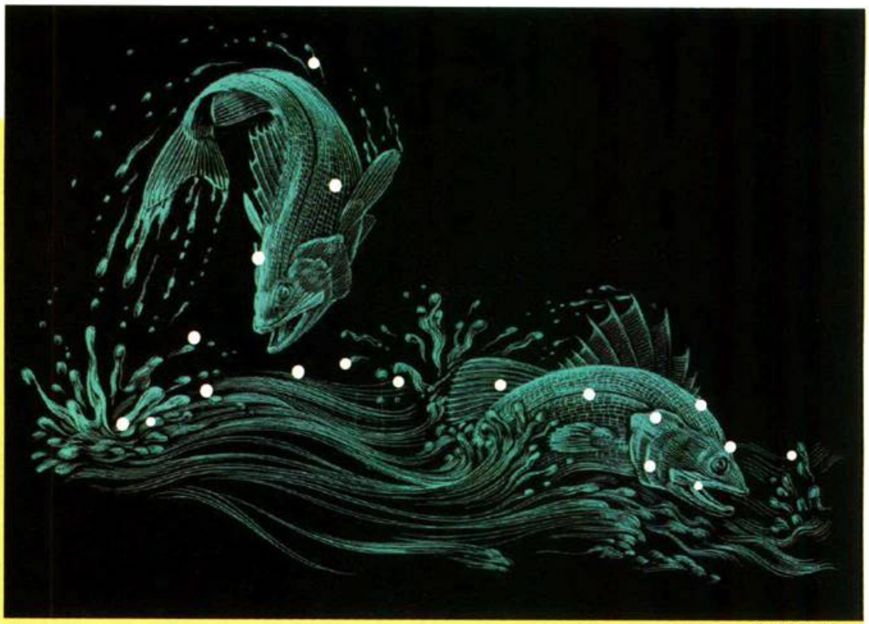
A third planet appears in the west after sunset, a bold light higher than either Venus or Mars. **Jupiter** shines brilliantly at magnitude –1.9, far brighter than Antares, which is nearby in early October. For North American observers, the Moon passes near the giant planet on October 26. Note how the Moon takes only two days to pass Venus, Mars, and Jupiter. The three planets now appear near one another in the sky, but they will pull much closer together by the middle of November.

When viewed through a telescope, Jupiter shows a 34"-diameter disk. Note its banded surface and flattened appearance; the planet's rapid rotation makes it noticeably wider across the equator than through its poles. Also look for Jupiter's four large moons — the Galilean satellites — as their orbits carry them into different configurations from one night to the next.

Pluto also lies near these three planets, but the 14th-magnitude planet is so faint you'll need at least an 8-inch scope to spot it. It appears in eastern Libra, where it forms a large triangle with Jupiter and Mars.

Lying almost due south after darkness falls are **Uranus** and **Neptune**. Both lie in eastern Sagittarius, with Uranus shining at magnitude 5.8 and Neptune at magnitude 7.9. The two finish their retrograde motions this month, resuming their normal eastward motions against the background stars. This is a sign that Earth has pulled far ahead of these worlds in its orbit around the Sun, and that the best time of year to see the two planets is ending.

The Starry Sky: **Pisces**


Keith Ward

When the Sun goes down on these autumn evenings, Pisces the Fish is ascending in the eastern sky. This constellation lies close to the celestial equator, so it rises nearly due east and sets nearly due west along your horizon, which it does around sunset and sunrise at this time of year.

From mid-northern latitudes, Pisces spends the brisk October nights arcing slowly across the southern sky. Because this constellation is faint, with no star brighter than about 4th magnitude, you'll need a dark sky to trace its pattern. First, look for the Great Square of Pegasus, an asterism consisting of four reasonably bright stars forming a large square. Pisces straddles the southeastern corner of the square.

This year there's a planet near Pisces — Saturn — which passed opposition last month and still shines conspicuously. You will see the planet more easily than the constellation because Saturn appears noticeably bright in the vicinity of these rather dim stars.

The Moon passes near Saturn on October 6. For three evenings after that, a full or nearly full Moon crosses the sky along with Pisces' stars. Although bright moonlight will wash out most of the stars of Pisces, the Moon can guide you to the general area of the sky occupied by this constellation. When the Moon has moved on, look in that same region for this long, V-shaped group on the sky's dome.

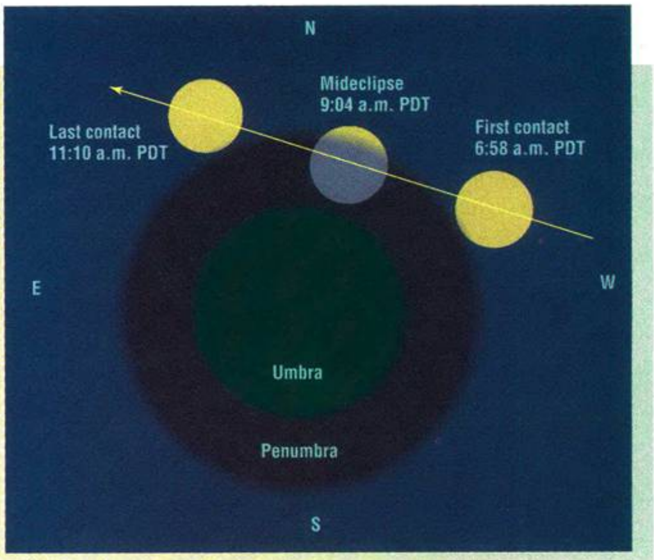
The two sides of this V represent the two fish in Pisces, sometimes called the Northern and Southern Fish. Some say the fish are tied together by a ribbon through their tails. A 4th-magnitude star located at the point of the V represents the place where the two fish are bound. This is the brightest star in Pisces, called Alrescha, from an Arabic word meaning "the cord."

Pisces also has a noticeable asterism, called the Circlet. This circle of stars lies at the head of the Southern Fish. Although the stars of Pisces are faint, the Circlet's compact shape makes it easier to see than you might imagine. I have glimpsed it from suburban skies on clear nights. Or use binoculars to locate the Circlet, and then trace the outline of the two fish.

In ancient Greek mythology, these fish represent Aphrodite and her son, Eros. They were swimming in a river when a monster, Typhon, suddenly appeared and frightened them. To escape the monster, they transformed themselves into fish, bound together so they would not become separated. To preserve the memory of this event, the fish were later placed among the stars.

Nowadays, the Sun is "in" Pisces — located in its direction in space — at the time of the vernal equinox in March. At the equinox, day and night are nearly equal in length. Oddly enough, the position of the Sun at this time is still called the First Point in Aries, from the time 2,000 years ago when the Sun was in Aries at the vernal equinox. Since that time the precession of the equinoxes has carried the vernal equinox out of Aries and into its western neighbor Pisces. — *Deborah Byrd*

Shadow on the Hunter's Moon



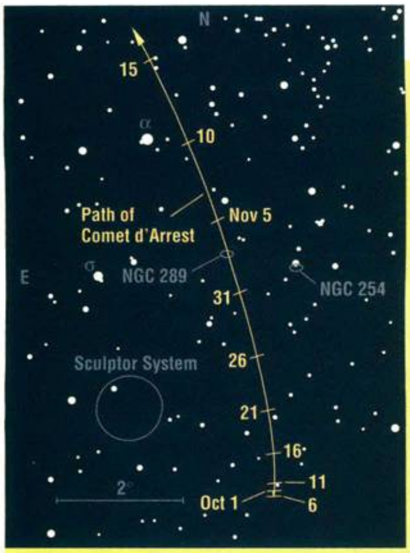
An eclipse of the Moon almost always accompanies a solar eclipse, and so it is with the October 24 total solar eclipse. Shortly before dawn on the morning of October 8, keen-eyed observers living along the Pacific coast of the United States and Canada may see a subtle shading on the southwestern limb of the Full Moon. At that time our satellite will be passing through the outer, lighter shadow of Earth known as the penumbra, creating a penumbral lunar eclipse.

Such eclipses are not as spectacular as their partial and total cousins. Using either low-power binoculars or your naked eye, look for a faint, dusky appearance along the southwestern limb of the Moon beginning shortly after the eclipse starts at 6:58 a.m. PDT. Observers in Alaska and Hawaii will get a slightly better view because the Moon remains above the horizon longer and so creeps deeper into Earth's shadow before dawn. The best views will come from Australia and eastern Asia, where the Moon rides high in the sky at maximum eclipse at 16h04m universal time.

Although the eclipse won't be visible to everyone around the globe, the Full Moon that plays host to Earth's shadow will be. And this isn't just any Full Moon either. The Full Moon following the Harvest Moon in September is known as the Hunter's Moon. It got its name because, for several days following the Hunter's Moon, the nearly Full Moon rises shortly after sunset and lights the landscape so hunters can spot their prey.

The cause of this behavior is the angle of the ecliptic relative to the horizon. The ecliptic traces the apparent path of the Sun across the sky, but the Moon follows nearly the same path. Because the Moon moves east in its orbit around Earth, Earth's rotation takes more than 24 hours to return the Moon to the same spot in the sky. Thus the Moon comes over the horizon an average of 50 minutes later each night. In the fall, the ecliptic makes its least angle with the eastern horizon in the evening, and the time between successive moonrises is relatively short, more like half an hour than the usual 50 minutes. — *R.S.*

Willy Groebner



Comet d'Arrest Skirts Sculptor Galaxies

Of all the periodic comets returning to the inner solar system this year, none offers the combination of brightness and favorable location that Comet d'Arrest does. And although d'Arrest is now slightly past its peak, it remains fairly easy to observe this month and next.

The comet begins October glowing at 8th magnitude in the constellation Sculptor. It remains nearly stationary for the first ten days of the month, then starts heading north. From about the 18th to the 24th, it passes 2° west of the Sculptor System, a large, faint galaxy in the Local Group. But don't expect to spot the galaxy in a telescope: This dwarf elliptical spreads across more than a degree of sky, giving it a very low surface brightness. Its brightest stars glow feebly at 18th magnitude.

On November 3, the comet passes just a few arcminutes west of NGC 289, a 12th-magnitude spiral galaxy. And on the 10th and 11th, it passes less than a degree from Alpha (α) Sculptoris, the 4th-magnitude star that ranks as the brightest in this faint constellation. (The finder map and table of coordinates show the comet's positions at 11 p.m. EDT, 10 p.m. CDT, 9 p.m. MDT, and 8 p.m. PDT.)

At about this same time, the comet lies only 5° south-southeast of the exquisite spiral galaxy NGC 253. If ever there were a great photo opportunity, this is it. A 150mm to 200mm telephoto lens will let you frame the galaxy, the comet, and the star with plenty of sky to spare. Piggyback your camera on an equatorially mounted scope and take several time exposures. (Using 400 speed film, try exposures of 4, 8, 16, and 32 minutes.) The contrast between the magnificent galaxy and dirty snowball in our solar system will make a photo well worth the effort. — *R.S.*

COORDINATES FOR COMET D'ARREST

Date	**R.A. (2000)**	**Dec.**
October 1	0h49.0m	–35°00'
October 6	0h49.0m	–35°05'
October 11	0h49.0m	–34°53'
October 16	0h49.2m	–34°25'
October 21	0h49.6m	–33°43'
October 26	0h50.5m	–32°51'
October 31	0h51.7m	–31°49'
November 5	0h53.5m	–30°40'
November 10	0h55.6m	–29°25'
November 15	0h58.3m	–28°06'

One more planet graces the evening sky this month, glorious **Saturn**. Now just one month past opposition, it lies in the east-southeast at sunset and arcs across the southern sky during the course of the night. Shining at magnitude 0.8 among the stars of Aquarius, it appears much brighter than the surrounding stars belonging to the watery constellations. If you peer at Saturn through a telescope, you will see only a thin line marking the position of the rings. In August Earth passed through the plane of Saturn's rings for the second time this year, and since then the rings have opened only slightly.

What of the final planet, **Mercury**? It joins all the other planets in the evening sky at the beginning of October, but it is done in by the shallow angle of the ecliptic. You won't be able to see it before inferior conjunction, when it passes between the Sun and Earth, on October 4/5.

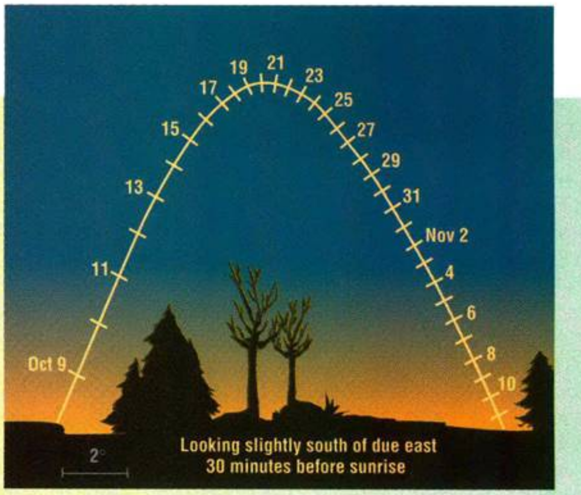
First Views:

Mercury at Its Morning Best

October offers an excellent morning appearance of Mercury. Despite shining at magnitude zero or brighter, however, the innermost planet is elusive because it never strays far from the eastern horizon. That means you'll need an observing site with an unobstructed horizon. Binoculars will help you spot the planet initially, but once you have, set them aside and see if you can glimpse it with your naked eye.

You can begin your search around the middle of the month. On the morning of the 15th, the planet rises 75 minutes before the Sun and lies 9° high 30 minutes before sunrise. It is best placed for viewing around the 20th, when it lies 18° west of the Sun, the maximum for this morning apparition. For an observer at 40° north latitude, the planet then rises 90 minutes before the Sun and lies 11° above the horizon half an hour before the Sun rises. By the end of the month, Mercury has begun its plunge back toward the horizon, and it will be lost from view by the end of the first week in November.

For telescope observers, Mercury's most visually interesting feature is its rapidly changing phase. When it first becomes visible during the second week of October, it presents a relatively large, thin, crescent-shaped disk. But Mercury's phase waxes rapidly as the planet approaches and then passes greatest elongation. On the 20th, Mercury appears 52 percent lit and on the 31st, the planet shows an 86-percent-lit disk. — *R.S.*



Looking slightly south of due east
30 minutes before sunrise

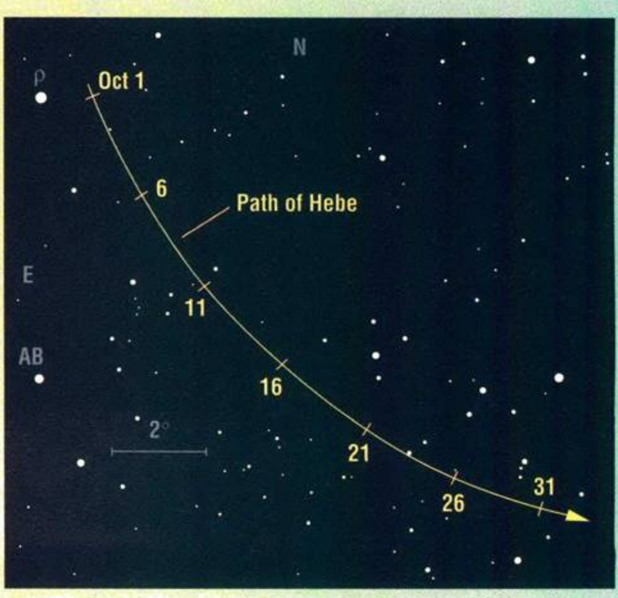
A Whale of a Show by Hebe

This autumn, observers will see a string of bright asteroids come to opposition. Following 18 Melpomene in September and preceding 7 Iris in November, this month offers the minor planet 6 Hebe. This 125-mile-diameter piece of solar system debris shines at magnitude 7.8 among the background stars of Cetus the Whale when it reaches opposition on October 18/19. Spectroscopy shows it to be reddish in color, but it is too faint to show up as anything but white in your eyepiece.

To find Hebe, use the finder chart or table of coordinates to zero in on the asteroid's position (shown for 11 p.m. EDT, 10 p.m. CDT, 9 p.m. MDT, and 8 p.m. PDT). The chart shows stars faint enough that you can probably identify Hebe by comparing your telescope's field of view with the map. To confirm your sighting, however, sketch or photograph the field and return to the same area a night or two later. When you look in the eyepiece and realize that one of the "stars" has moved, that wanderer will be Hebe. — *R.S.*

COORDINATES FOR HEBE

Date	R.A. (2000)	Dec.
October 1	2h23.7m	–12°16'
October 6	2h21.5m	–13°21'
October 11	2h18.6m	–14°19'
October 16	2h15.2m	–15°10'
October 21	2h11.5m	–15°52'
October 26	2h07.6m	–16°23'
October 31	2h03.8m	–16°42'



You should, however, be able to spot it in the eastern morning sky beginning about a week after that. This dawn apparition is the best of 1995 for Mercury, for the same reason the evening one is poor. The ecliptic makes a very steep angle relative to the eastern horizon before dawn at this time of year, placing Mercury as high as possible in the predawn sky.

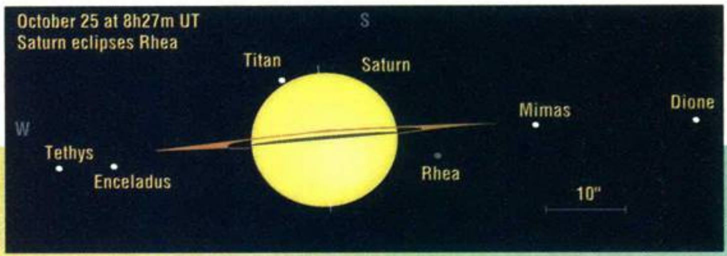
Greatest elongation comes on October 20, when Mercury lies 18° west of the Sun and appears 11° high 30 minutes before sunrise. The planet then shines at magnitude –0.5, bright enough to spot easily in the twilight if you use binoculars. The view of Mercury through a telescope will show a 7"-diameter disk that is just about halflit. ☐

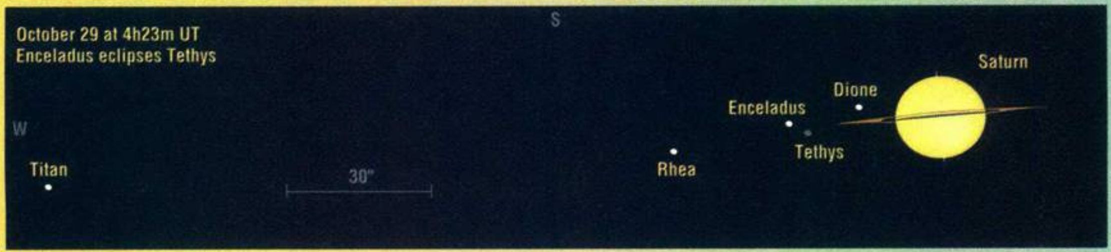
Deborah Byrd writes and produces the daily "Earth and Sky" radio series. Rick Shaffer is a writer living in Arizona.

Observer's Challenge:
Hide and Seek Among Saturn's Satellites

October finds Saturn once again giving us a peek at her magnificent rings. However, it is just a peek: Although we are looking at the fully illuminated north face of the rings, the rings are still nearly edge-on to our line of sight so they appear as a bright line crossing the disk of the planet.

Besides watching the changing aspect of the rings, another exciting pastime for observers of Saturn is following the eclipses and occultations of its satellites. Many occur during October, and with Saturn now visible for much of the night (it was at opposition just last month), a healthy number can be seen from any given location. The table lists all the significant events that take place during October, while those colored red are visible from at least some of North America. The best-timed events for North American observers are the Enceladus eclipse of Mimas on the 3rd, the Tethys eclipse of Enceladus on the 9th, the Saturn eclipse of Rhea on the 25th, the Enceladus eclipse of Tethys on the 29th, and the Tethys eclipse of Rhea on the 30th. — *R.S.*


October 25 at 8h27m UT
Saturn eclipses Rhea


October 29 at 4h23m UT
Enceladus eclipses Tethys

EVENTS OF THE SATURNIAN SATELLITES

Date	Begin Time	End Time	Event	Type of Event	Light Loss	Distance
October 1	12h02.9m	12h18.4m	Saturn eclipses Titan	Reappearance	—	1.6
October 3	2h57.9m	3h00.9m	Enceladus eclipses Mimas	Partial	51%	3.1
October 4	14h03.2m	14h06.2m	Enceladus eclipses Tethys	Annular	20%	3.7
October 7	10h30.5m	10h33.5m	Mimas eclipses Rhea	Partial	5%	3.3
October 9	8h06.4m	8h07.7m	Tethys eclipses Enceladus	Partial	9%	3.6
October 17	11h17.1m	11h32.3m	Saturn eclipses Titan	Reappearance	—	2.1
October 22	12h28.2m	12h31.2m	Tethys eclipses Dione	Partial	43%	4.2
October 24	10h19.9m	10h21.9m	Tethys eclipses Enceladus	Partial	28%	3.7
October 25	8h25.7m	8h28.7m	Saturn eclipses Rhea	Reappearance	—	1.6
October 25	19h15.0m	19h19.7m	Dione eclipses Rhea	Partial	21%	6.3
October 25	19h37.7m	19h46.7m	Titan eclipses Mimas	Total	87%	2.8
October 29	4h21.9m	4h23.9m	Enceladus eclipses Tethys	Annular	28%	3.0
October 29	20h53.8m	20h56.8m	Saturn eclipses Rhea	Reappearance	—	1.6
October 30	2h16.4m	2h19.7m	Tethys eclipses Rhea	Partial	19%	4.2

Begin Time: Universal time at beginning of event. (Subtract 4 hours to convert to EDT, 5 hours for CDT, 6 hours for MDT, and 7 hours for PDT.) **End Time:** Universal time at end of event. **Event:** The nature of the event and the objects involved. **Type of event:** Whether the event is partial, total, or annular, or a disappearance or reappearance. **Light Loss:** The percent of light lost by the eclipsed satellite at midevent. **Distance:** The apparent distance of the satellite from Saturn's center expressed in Saturnian equatorial radii.

SEE THE ORIONIDS

Cool, crisp air and a Moon-free sky combine to offer great potential for this year's Orionid meteor shower.

by Philip Bagnall

Seth Horowitz

SKIMMING THE PLEIADES, an Orionid streaks onto film during the 1976 shower.

Flash! A brilliant streak lights the ground as you wheel around and look up to see the remains of a bright meteor. Nothing quite gets the blood going like being under the stars and seeing the sudden, unexpected luminous trail of a meteor overhead. Fortunately, the best meteor shower of the next few months, the Orionids, takes place this month.

Summer has gone and the nights are getting longer and colder — perfect conditions for meteor hunting. And each year at about this time, meteor observers look forward to a late autumn and winter of active, often bright showers. The first of these is the Orionids which, because of the lack of moonlight, appears to be the most promising.

Anatomy of a Shower

The Orionids rank among the best meteor showers. Although not as prolific as the Perseids in August or the Geminids in frigid December, they put on a fine display of shooting stars which, at maximum, can reach 25 meteors per hour.

AN ORIONID FLASHES through Pyxis on October 21, 1993.

Wallace Baldwin

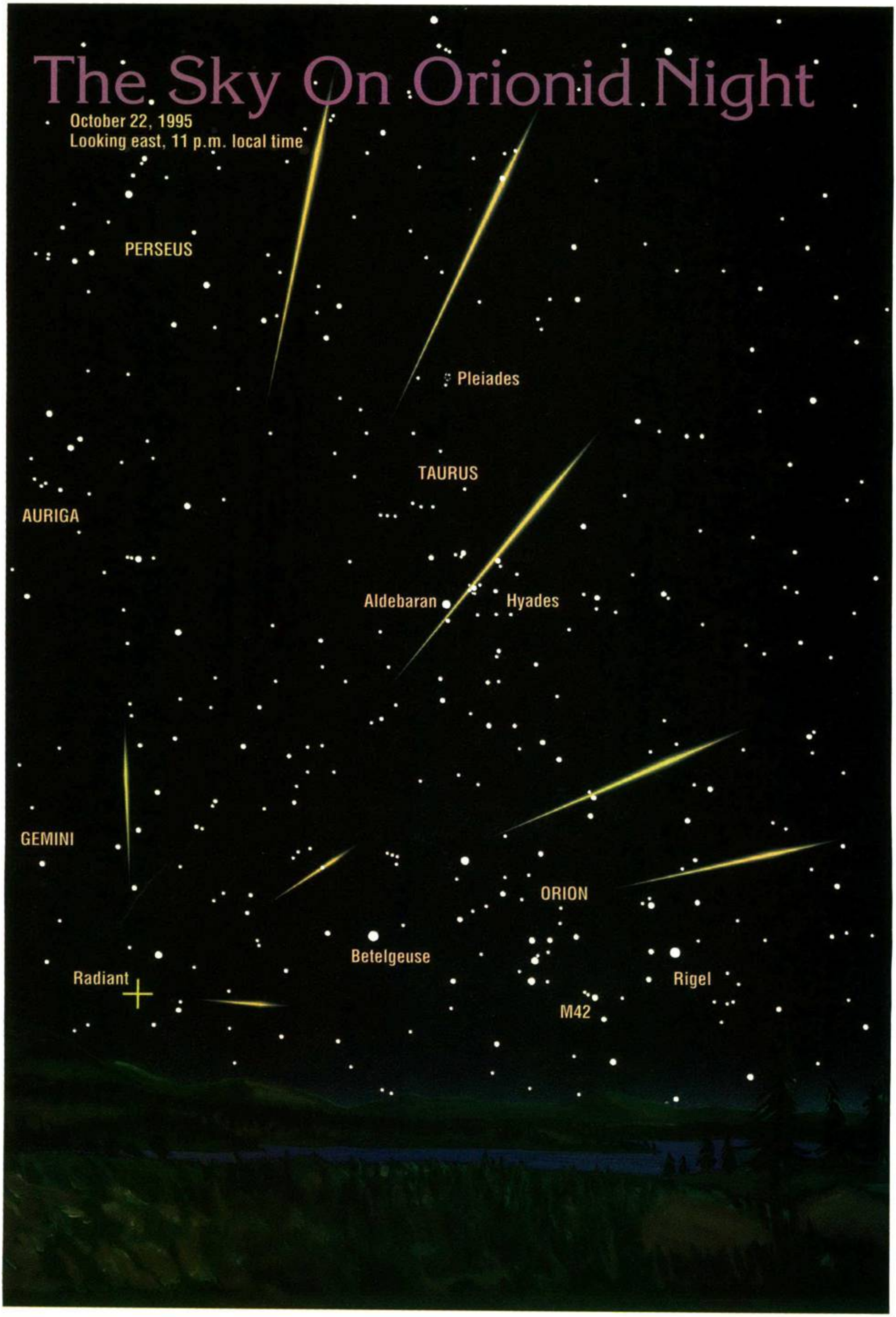
The shower runs from about October 16 through October 27, peaking on the 22nd and 23rd. This year, the Moon will be almost new as the Orionids rise to maximum activity, ensuring dark skies and a chance to observe the fainter meteors the shower often produces.

On any given night you can walk out under the stars and see a few sporadic meteors. These common meteors are not associated with any major shower and appear to come from points all over the sky. As with all meteors, they are bits of cosmic rock, most as small as sand grains, that fall into Earth's atmosphere and vaporize due to the great heat caused by friction with air molecules. As they burn up, these meteoroids cause the brief flash of light we see as a shooting star.

Unlike sporadics, however, Orionids seem to come from the small area of sky that marks Orion's right elbow. This roughly circular area, called the radiant, is an optical illusion. All the meteroids in the Orionid stream travel in orbits that are more or less parallel to one another. However, just as the parallel lanes on a

The Sky On Orionid Night

October 22, 1995
Looking east, 11 p.m. local time


PERSEUS
Pleiades
TAURUS
AURIGA
Aldebaran
Hyades
GEMINI
ORION
Betelgeuse
Radiant
Rigel
M42

Orionid Relatives

The Eta Aquarids are the spring component of the Orionids. Most Eta Aquarids are visible between April 30 and May 12, with the peak on May 5 and 6. The radiant lies at 22h20m, −1° and rates reach about 35 meteors per hour. (Unfortunately, maximum occurs at Full Moon next year, so the fainter meteors will be washed out.)

WATCH FOR **sporadics, meteors that don't belong to any particular shower — as in this November fireball (right), recorded near Orion.**

Glen Sinacore

freeway appear to converge at a point in the distance, the parallel trajectories of the meteors seem to converge to a point on the celestial sphere. They therefore appear to radiate from this point.

As Earth passes through the stream and emerges from the other side, the radiant appears to drift slowly across the sky from night to night. On October 16, at the start of the shower, the radiant will be at right ascension 5h54m, declination 14.2°. By October 22, it will have moved to 6h49m, 15.7°. There may be other radiants active at this time in the same area of sky. This is not unusual and may indicate several active filaments in the meteor stream that produces the Orionids. The result is that the period of maximum activity can last for some time — from several hours to a few days — unlike some showers that peak for less than an hour.

The shower offers some other advantages. Orionid meteors are very swift as they streak across the sky. Not surprising, really, when you consider they enter the atmosphere at velocities of around 40 miles per second. In fact, with the exception of the Eta Aquarids, the Orionids are the zippiest of all meteor showers. These greater velocities, however, mean that the meteors burn up at higher altitudes than most meteors: usually between 60 and 75 miles.

When a meteoroid plunges into the atmosphere at hypervelocity, the radical change from an almost-no-density to a high-density environment causes a dramatic conversion of a little mass into a lot of energy. The meteor drills into the atmosphere like a bullet hitting a stone wall. Atoms in the air "sandblast" the meteoroid's surface, stripping away its electrons and creating an ionized tube in the atmosphere. Electrons recombining with the atomic nuclei produce photons, which we see as a sudden streak of light in the night sky.

Observing the Orionids

Meteor observing is one of the easiest of all astronomical pursuits, requiring only modest preparation. Before you begin your meteor watch, prepare a few things. Check out a star chart to get some idea where the radiant lies. Fortunately, Orion is easy to recognize, so you should have no trouble in locating the radiant when you start to observe. This time of year the constellation rises in the east in the late evening, and is well up and brightly visible by midnight. Make sure you're wearing plenty of warm clothing — it can get bitterly cold in the dead of night — and make a thermos of hot tea or coffee. Sandwiches or other high-energy snacks will help keep you alert — try something rich in carbohydrates. Grab a red flashlight, a pen and a notebook, and your copy of ASTRONOMY.

The basic idea behind meteor observing is simple. Don't look at the radiant. Meteors in that area appear only as short, faint streaks. Instead, set your sights on an area of sky about 45° from the radiant and at about 45° altitude. Choose the darkest part of the sky you can, preferably near a constellation you're familiar with. If you're surrounded by street lights, venture into the country for a darker sky.

Relax in your lawn chair and carefully look skyward. When you see a meteor, estimate its brightness by comparing it to the stars that surround it, then ask yourself these questions: Did it have a persistent train? If so, what did the train look like? Was it nebulous? Did it appear hollow, or did it have a bright spine? What color was it? How long did it last?

When you are sure you've remembered all the details, write them down and add the time. If the train appeared unusual, make a quick sketch of it. If the magnitude was brighter than −4.0, the meteor is

George Livadaras

And the Rest of the Story

Meteor observers love the northern winter. The cold, crisp air and long nights are perfect for observation. And they are richly rewarded with a plethora of showers. Two of these showers — the Geminids and the Quadrantids — are often more active than the August Perseids.

Despite interference from moonlight, there will still be plenty of bright meteors to see. So relax for a couple of hours and watch nature's own spectacular fireworks display.

Shower	**Period**	**Maximum**	**Radiant**	**ZHR***
Taurids	Oct. 20-Nov. 3	Nov. 3	3h44m, 14°	10
Leonids	Nov. 15-17	Nov. 17	10h8m, 22°	15
Geminids	Dec. 7-16	Dec. 13	7h28m, 32°	90
Ursids	Dec. 17-25	Dec. 23	14h28m, 78°	5
Quadrantids	Jan. 1-6	Jan. 3	15h28m, 50°	100

*Zenithal Hourly Rate (ZHR), the number of meteors you should expect to see under perfect conditions with a naked-eye limiting magnitude of 6.5 and with the radiant directly overhead.

Terence Dickinson

A FAINT ORIONID streaks through Perseus.

What to Bring to the Meteor Hunt

Taking a few items with you to your favorite meteor observing location will make the experience more comfortable and enjoyable. Be sure not to forget any of the following items:

- Sleeping bag or blankets for warmth
- Lawn chair or any comfortable chair
- Thermos of hot coffee, tea, or cocoa
- Red-lensed flashlight
- Star chart to record meteor tracks
- Binoculars to observe trains
- Camera equipment and film
- Bug spray
- Note paper for recording observations
- Boom box for soothing music
- Food

officially a fireball and you should make a note of its path: again, a sketch would help. Finally, decide whether or not the meteor came from the radiant by tracing its path back across the sky. If it intersects the radiant then it was an Orionid. If not, the meteor was probably one of the many sporadics entering the atmosphere each day.

Try to observe for about an hour before taking a break. Breaks are important. They give you the chance to stretch your legs, rest your eyes, and wake yourself up. Beware of feeling too cozy, especially if it is cold — it could be an early sign of hypothermia. If you get too tired, or too cold, pack it in for the night.

The Halley Connection

The Orionids are closely associated with Halley's Comet as is the Eta Aquarid meteor shower in May. In fact, the Eta Aquarids and the Orionids are one and the same stream. To understand how this can be we need to look at a little history of Halley's Comet.

Like all other comets, Halley is basically a dirty snowball. It consists mainly of frozen water peppered with dust particles left over from the birth of the solar system 4.5 billion years ago. In the cold wastes of the outer solar system, comets are inactive. But as they approach the Sun and warm, their ices sublimate, turning directly to gas without going through a liquid phase. This transformation ejects trapped dust particles into new orbits around the Sun. The particles, or meteoroids, form a meteoroid stream. When Earth passes through the stream, the meteoroids produce a meteor shower.

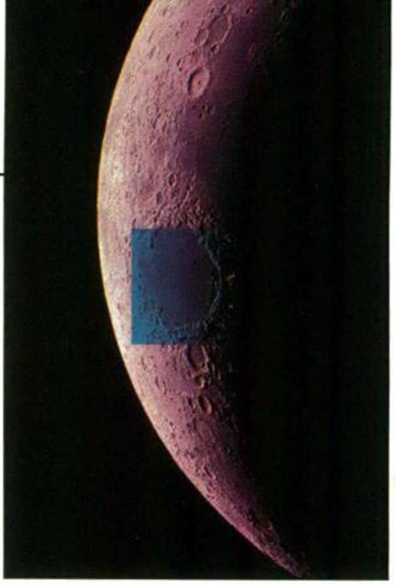
In the case of Halley's Comet, Earth passes through the stream twice each year: once in October, which produces the Orionids, and again in May when we see the Eta Aquarids. Because the stream's orbit is inclined to that of Earth's, we encounter the stream in October as the particles travel from north to south. The shower then favors observers in the Northern Hemisphere. Six months later, we cross the stream as the meteoroids pass from south to north, and the shower favors the Southern Hemisphere.

So when you see the Orionids this October, you will bear witness to the dramatic end of dust particles that once belonged to Halley's Comet for most of the 4.5-billion-year history of our solar system. □

Philip Bagnall is an amateur astronomer living in England.

Portal to the Ancient Moon:

MARE CRISIUM



Jim Baumgardt

Explore a region that is a lunar maria and an ancient crater basin in one: Mare Crisium.

by Cassandra Coombs

Back in the depths of time, some 3.85 billion years ago, when the solar system was still in its infancy and swarming with the leftover debris from which it formed, a sizable chunk of this primordial flotsam slammed into the northeastern quadrant of the Moon. The resulting explosion scooped out a 570-kilometer-wide basin and sent shock waves across the surface in all directions. Boulders, pebbles, and talcum-like dust rained down around the basin, creating a debris blanket almost 200 km wide.

As with other major basins on the lunar nearside, the impact also generated a series of fractures within the lunar crust immediately below and adjacent to the impact site as the lunar rock rebounded from the shock. Over the next three hundred to five hundred million years, lava oozed through these fractures, gradually filling an area on the Moon equivalent to the United Kingdom. Soil samples returned by Soviet landers date the Crisium mare fill at between 3.6 billion and 3.3 billion years.

You can still see this lava-filled basin, now called **Mare Crisium**, or the Sea of Crises. At moonrise during the full phase, it lies near the northeastern limb of the Moon between the 1 and 2 o'clock position, a gray mole on the pallid face of the "Man in the Moon."

The view is even better in a telescope with a low-power eyepiece. Like other lunar maria, the floor of Mare Crisium is very smooth and flat. Whatever features once existed on the basin floor have long been covered by lava. Most dramatic of all, though, is how the featureless floor lies in stark contrast to the craggy mountains ringing the basin. You could sneak Mount McKinley next to most of these mountains and it would be nicely camouflaged.

If you want to see Mare Crisium in all its splendor, all you need is a small telescope — a garden-variety 60mm or 80mm refractor will do. Boost the magnification to around 100x and take the tour. Keep in mind that being practically on the limb, you'll see the most detail when the sunlight angle is low. Sunrise in the basin occurs between two and four days after new Moon; sunset is complete four days after Full Moon.

Working your way leisurely around the basin, you will encounter craters, wrinkle ridges, lava plains, pyroclastic deposits (rocks of volcanic origin), fractures, and two of the Russian Luna landing sites. With the exception of the Luna sites, most of the large-scale features will be fairly obvious, if the sunlight angle is favorable. The more challenging ones, though, may require you to push your eye and your telescope to its limits. It should come as no surprise that there are observing challenges aplenty in the Sea of Crises.

We begin our traverse in the northeastern sector of the mare. The grazing light of the First Quarter phase reveals two long wrinkle-ridge systems extending north to south along the edge of the gray plain. Like most lunar features, they are designated by their Latin name. In this case, they indicate a network of mare ridges, which collectively are called dorsa. (If it were only one mare ridge, we would say dorsum.) The uppermost network of wrinkle ridges, **Dorsa Tetyaev**, extends for about 150 km. The more southern of these two eastern ridges, **Dorsa Harker**, is over 200 km long.

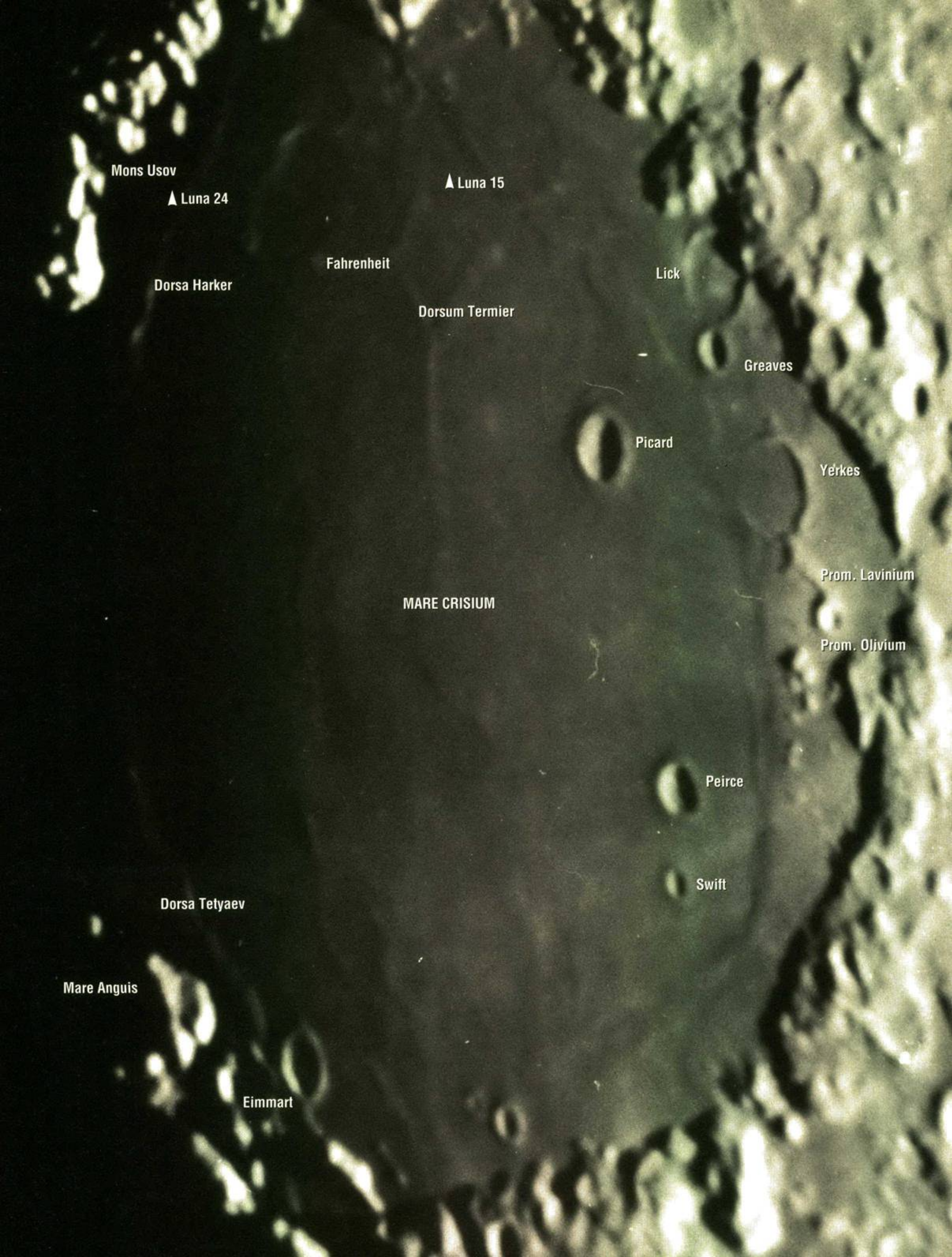
Wrinkle ridges form when the mare surface settles. Often, the settling reveals structures from past geologic events beneath the lava layers. Locations of features such as old basin rims and buried craters can be identified by their silhouette on the mare surface.

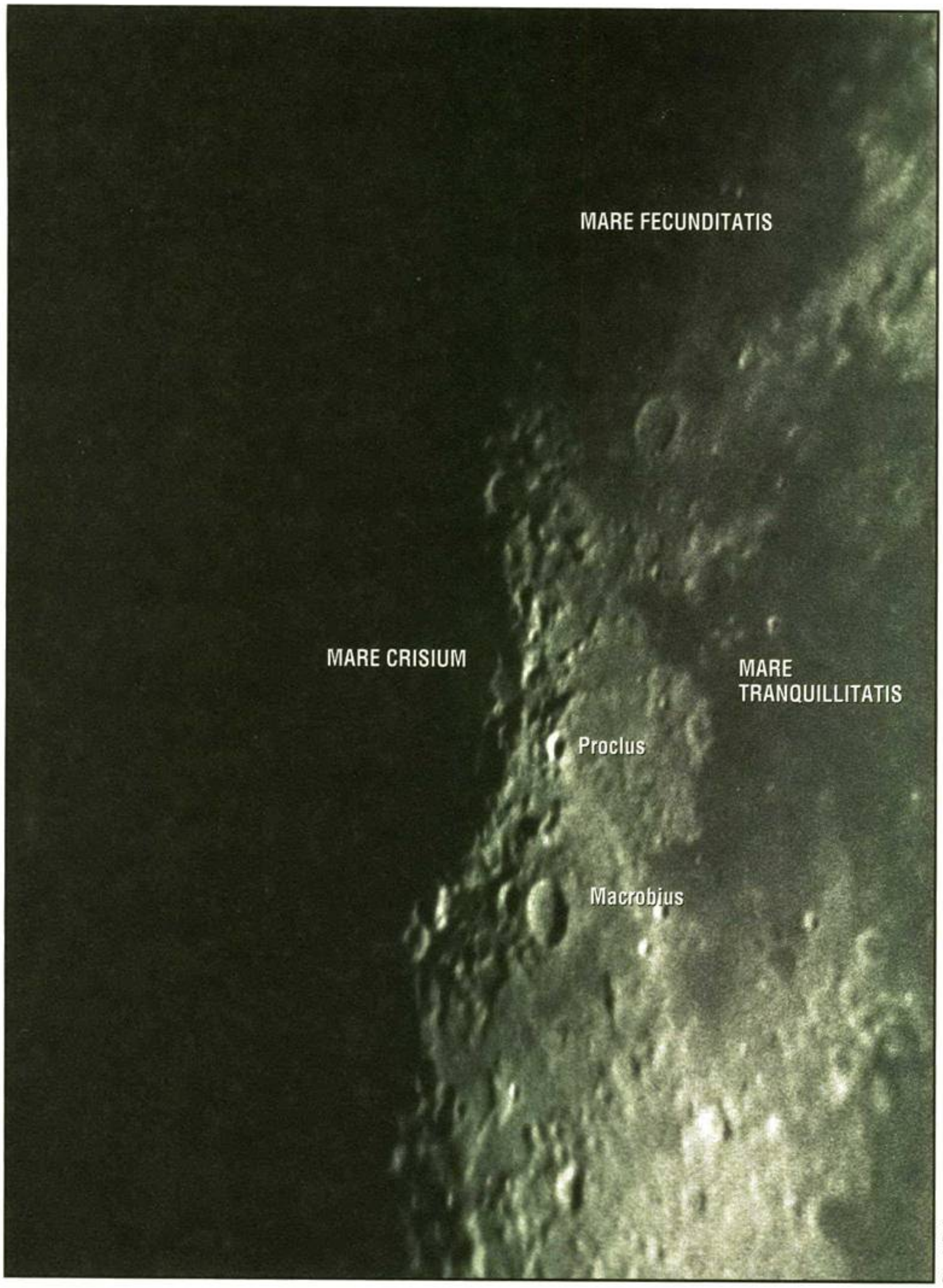
Just northeast of the basin rim, where the smooth plain gives way to craggier terrain, is the crater **Eimmart** and the irregular plain, **Mare Anguis**. Eimmart is a shallow, slightly elongated crater, 46 km at its greatest span. This crater has a flat floor with some terracing inside of the rim. Just to the southeast lies Y-shaped Mare Anguis, the Serpent Sea, a region flooded by Crisium lavas that leaked out of the basin. The foreshortening effects of looking along the moon's curved limb give this flat, low-lying mare region an elongated shape in the telescope.

Further to the south along the eastern border of Mare Crisium, are the craters **Alhazen** and **Hansen**. Both craters — relatively recent events in Crisium's history — were created when objects between 5 and 8 kilometers in diameter smacked obliquely into the lunar surface. Alhazen, the northernmost of the two, is 33 km across and is distinguished by a sharp, distinct rim wall. This bowl-shaped crater has a flat-bottom floor. Just

CRAGGY MOUNTAINS enclose Crisium basin, which is best seen when the sunlight angle is low — at lunar sunrise, two to four days after New Moon, or at sunset, four days after Full Moon. This view shows the sunset angle. South is up.

Jean Dragesco


Mons Usov
Luna 24
Luna 15
Fahrenheit
Dorsa Harker
Lick
Dorsum Termier
Greaves
Picard
Yerkes
Prom. Lavinium
MARE CRISIUM
Prom. Olivium
Peirce
Swift
Dorsa Tetyaev
Mare Anguis
Eimmart



Derek Robson

CHALK MARK ON THE MOON, Proclus, one of the Moon's brightest craters, looks like a white crescent as the Sun sets over western Mare Crisium, a day or so after Full Moon. The eastern realms of Mare Tranquillitatis and northern Mare Fecunditatis lie in the foreground.

south of Alhazen lies the elongated crater Hansen. This crater measures 40 km north to south and features a moderate central peak.

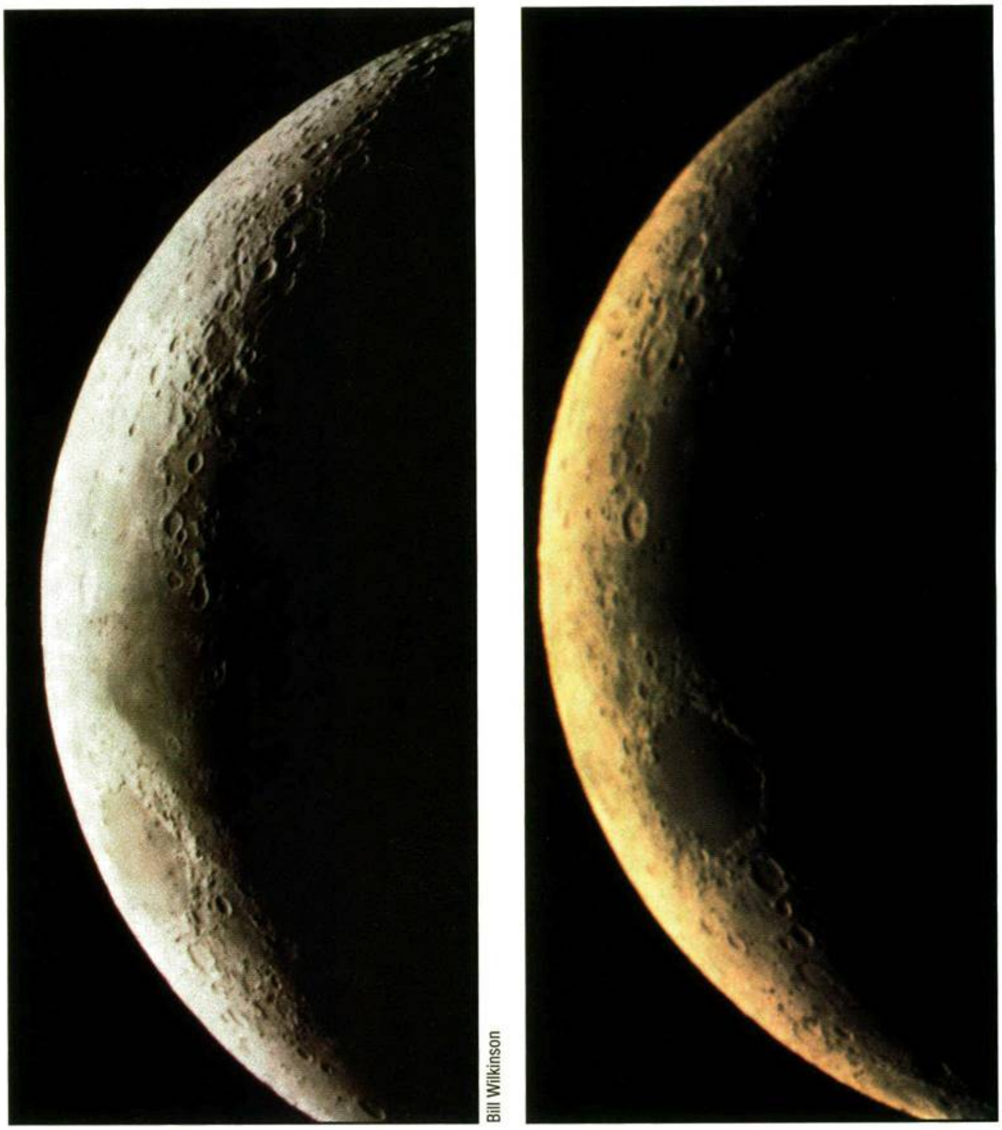
Continuing southward along the inner rim of the Crisium basin we encounter the first of two Luna landing sites in this region. **Luna 24**, the last in the series of Soviet landers and the third of that class of spacecraft to successfully return soil samples to Earth (in August 1976), is located just west of Dorsa Harker. The actual spacecraft is not visible in any size telescope, but you can pinpoint the area. It lies between the tiny crater **Fahrenheit** (6 km) and the southernmost reaches of Dorsa Harker. Look carefully for Fahrenheit, which is little more than a pockmark that requires just the right low-angle lighting to pick out.

At the southern tip of Dorsa Harker lies **Mons Usov**. This is a tiny mountain whose peak juts out above the surrounding mare plain. The edifice is but 15 km in length. While in the southeast quadrant of Mare Crisium you might enjoy shifting your telescope to the east to **Condorcet**, a 73-km-diameter crater with a dark, flat floor analogous to the mare plains in Mare Crisium. Scientists think this large crater was filled in by molten lava, possibly associated with the same volcanic outflow that inundated the floor of the Crisium basin. While gazing around this crater, note the small terraces present on its outer flanks. These formed when portions of the inside wall collapsed and slumped to the floor.

Scanning further to the south, we encounter **Auzout**, a 33-km crater that lies within the inner ejecta blanket of Mare Crisium. Butting up against the southern tip of Auzout is the 22-km crater **van Albada**. Superposed on van Albada is yet a still smaller crater. (You may need to crank up your telescope's magnification somewhat.) Notice the superposition of these two craters. Superposition relationships like this help planetary scientists determine the different ages of a planet's surface. Because the smaller crater sits inside van Albada, we can infer that it occurred later, or after van Albada was made. By counting the number of craters within a known area, planetary scientists can determine a cratering frequency, and through comparison with crater densities of other similar areas, derive a relative age for the different surfaces.

Returning to the basin rim, a third prominent mare wrinkle ridge exists just west of Mons Usov. Train your telescope on the point where the ridge joins the basin rim. This second ridge, known as **Dorsum Termier**, runs north to south and is 90 km in length. It shows up particularly well a couple of days after Full Moon. At the southern end of Termier, where the wrinkle ridge appears to blend into the basin plain again, is the landing site of **Luna 15**, which crash-landed on the surface July 13, 1969, one week before astronaut Neil Armstrong made humankind's first lunar perambulation. In a telescope, a wedged-shaped mountain projecting onto the plain from the basin rim comes close to pointing directly at the site.

Traveling up along the western edge of the basin floor from south to north you will see four distinct craters: **Lick**, **Greaves**, **Yerkes**, and the most prominent crater in the basin itself, **Picard**. The craters Lick (31 km) and



Bill Wilkinson

Yuh-Tsuen-Li

TURNING THE OTHER CHEEK, the Moon's orbit causes it to "librate," or appear to wobble slightly. Features along the eastern and western limbs alternately face more in our direction. A good time to observe Mare Crisium is during maximum libration, when the eastern limb is most exposed.

Yerkes (36 km) have been filled in with the same mare lavas that now cover the floor of the basin. Greaves (14 km) and Picard (23 km) are simple bowl-shaped craters, though Picard has an extremely sharp, fresh-looking rim. While in this area, take a look around. You will see several other flooded craters, which formed when the lavas filling Mare Crisium spilled over the crater walls or came up through the floor. Once the lavas settled and cooled only the higher portions of the once prominent craters were left exposed.

Embedded in the floor of the basin a little further to the north are the craters **Peirce** (18.5 km) and **Swift** (11 km). Both are bowl-shaped craters marking impacts occurring after the mare lavas had cooled.

Lying to the southwest in the Crisium highlands just beyond the basin rim is the crater **Proclus**. This 28-km-wide crater is easily distinguished by the bright ray system associated with it. In fact, Proclus is the second-brightest spot on the lunar surface after Aristarchus. Because its rays extend across the surface of the mare, Proclus must be a relatively recent event, one that occurred within the same time period as Copernicus Crater, less than 50 million years ago. Notice that the rays extend in all directions except to the southwest. Scientists think this shows that the object approached at a fairly low angle, coming from the southwest. The impact sent material in all directions away from its incoming trajectory.

Bring your field of view back to the western rim of Mare Crisium—west-northwest of Yerkes. There you will see two very prominent "capes" or promontories. On Earth, a promontory is high land that juts into, or overlooks, low land or a body of water. Except for the aqueous aspect this description holds for these two features, named **Promontorium Lavinium** and **Promontorium Olivium**. At one time, it was thought that these two features were connected by a bridge because of the way the structures here are illuminated in the moments just after sunrise and before sunset. It was later learned, however, that the "bridge" separating the two promontories actually consists of two eroded craters.

If you don't like the view of Mare Crisium tonight, wait a few months and it will change. The Moon's orbit is eccentric and its orbital velocity inconstant. Together these forces cause the Moon to librate, or oscillate, in longitude about 7 or 8 degrees. Thus, at times, the eastern limb turns more our way while at others the western limb is exposed. (A similar phenomenon occurs in lunar latitude as well, hence the Man in the Moon is always shaking his head and nodding simultaneously.) During a favorable libration when the eastern limb is most exposed, Mare Crisium is oriented more directly toward Earth, providing a nearly bird's-eye-view of its features. An interesting, albeit long-term, project would be to sketch these features when the Moon is librating at maximum (east limb exposed) then minimum (west limb exposed), and to compare the sketches for differences in light and shadow. To make it a real one-to-one comparison, you would need to do your sketching when the Moon was at the same phase but at an opposite libration angle. Features that were difficult to see, or completely unseen, during minimum libration may be more prominent during maximum libration.

Lunar maria represent a geologic conjunction in time, where ancient terrain meets very ancient terrain. Mare Crisium is no exception. Features have been reshaped; whole mountains, faults, and valleys covered over. You may have seen it before, but it's worth another look. As you explore the region with your telescope, consider that the stark, unyielding floor of Mare Crisium masks a geologic record that dates back to the beginning of the solar system itself. ☐

Cassandra Coombs is a geologist and the campus director of the South Carolina Space Grant Consortium at the College of Charleston, South Carolina.

ASTRONOMICAL COMPUTING

Sunrise on the Moon

What lunar features are well placed for viewing and photographing tonight? Let your personal computer supply the answer.

by David Bruning and Richard Talcott

Sunrise on Ptolemaeus: As darkness gives way to light, jagged shadows cast by the peaks that form its eastern rim streak across the giant lunar crater's ancient floor. Meanwhile, several saucer-shaped craters formed by later impacts pop into view, so shallow that they appear only at sunrise or sunset.

The Moon is full of features, like Ptolemaeus, that appear stunning under grazing sunlight but ho-hum at best as the Sun rises higher in the lunar sky. The key to getting a good view? Knowing when the terminator, the dividing line between night and day on the Moon, will cross a given region and throw its features into sharp relief.

Unfortunately, few sources provide such information. Almanacs usually give just the times of the Moon's new, full, and quarter phases. And most lunar guidebooks are somewhat vague, saying, for example, that a particular feature appears best seven or eight days after New Moon. But to see the most detail in a telescope, or to capture it on film, you have to catch the lunar shadows just right. The quickest and easiest way to do that is to have your personal computer perform the calculations.

The number you need to know is the Sun's selenographic colongitude, a fancy name for the longitude on the Moon where the Sun is rising, which marks the position of the sunrise terminator. The colongitude depends on the angle between the Sun and Moon as seen by an observer on Earth and increases by 12.2° every 24 hours. Thus the program needs to calculate the apparent positions of both the Sun and Moon. For more accuracy, the program must also correct for the elliptical orbits of the Moon and Earth and for the slow rocking motions of the Moon's visible hemisphere known as lunar librations.

ASTRONOMY's lunar sunrise program, called COLONG.BAS, is written in QBasic, the version of BASIC now supplied with DOS on all PC-compatible computers. It consists of four main subroutines. The first determines the Julian date corresponding to the date of observation. The Julian date measures the number of days and fraction of a day that have elapsed since noon Greenwich time on January 1, 4713 B.C. Because every Julian century has exactly 36,525 days, astronomers can figure intervals between dates in different months and years by simply subtracting.

The second and third subroutines, respectively, compute the precise positions of the Sun and Moon in the sky. To make the calculations easier, both subroutines assume that the observer lies at the center of Earth. Observers more comfortably placed on Earth's surface will find that this introduces a slight error into the final colongitude, but it amounts to just a small fraction of one degree.

The final subroutine determines the lunar librations. The program calculates the largest optical libration, which results from the Moon rotating on its axis at a constant rate but revolving around Earth in an elliptical orbit at an ever changing rate. The difference causes our view of the surface to change over the course of the Moon's monthly orbit.

Once you have entered the program listing, select RUN from the pull-down menu and the program will ask you to enter the time you plan to observe. As an example, suppose you plan to observe from the eastern time zone on the evening of October 1. From mid-northern latitudes, the sky gets reasonably dark by 8 p.m. local daylight time, or 20 hours in 24-hour mode. When the program asks you for the time, enter 1995 for the year, 10 for the month, 1 for the day, and 20 for the hour. The program then displays the selenographic colongitude of 4°, meaning the terminator is just past the Moon's central meridian, or just past First Quarter phase. (Coincidentally, the Sun is just rising on Ptolemaeus.)

The program is initially set to accept times in eastern daylight time. For other time zones, or when standard time is in effect, you need to modify the zone statement that appears near the beginning of the Julian

Good Lunar Hunting Grounds

Crater	Map	Latitude	Long.	Diam.	Feature	Location
Arzachel	55	18S	2W	97	terraced walls, valleys	southern highlands
Albategnius	44	11S	4E	136	ring mountain	southern highlands
Capuanus	63	34S	27W	60	flooded crater	Palus Epidemiarum
Copernicus	31	10N	20W	93	terraces	Mare Insularum
Fra Mauro	42	6S	17W	95	walled plain	Mare Insularum/Mare Cognitum
Flamsteed P	40	3S	44W	100	ghost crater	Oceanus Procellarum
Hesiodus A	54	30S	17W	15	double walls	Mare Nubium
Jansen	36	14N	29E	23	flooded crater	Mare Tranquillitatis
Kies	53	26S	23W	44	flooded crater	Mare Nubium
Messier A	48	2S	48E	11	crater with cometlike rays	Mare Fecunditatis
Ptolemaeus	44	9S	2W	153	walled plain	southern highlands
Taruntius	37	6N	47E	56	nested walls	Mare Fecunditatis
Wargentin	70	50S	60W	84	raised crater floor	southwestern limb

Map refers to the map number in Antonín Rükl's *Atlas of the Moon*. Diameters are measured in kilometers.

On the Moon, the line of 0° longitude bisects the Earth-facing hemisphere. The program treats north latitudes and east longitudes as positive, south latitudes and west longitudes as negative.

COLONG.BAS

```
REM — Determine the position of the Moon's terminator
INPUT "Enter the Year   ", YR
INPUT "        Month  ", MN
INPUT "        Day    ", DAY
REM — Enter the time in 24-hour mode, (e.g. 10:30 pm = 22.5)
INPUT "        Hour in 24-hour format ", HR
CALL JULIAN(HR, DAY, MN, YR, T)
T2 = T * T
REM — RAD converts degrees to radians for trig functions
RAD = .0174533
CALL Sun(RAD, T, T2, L, M, R, LAM0)
CALL Moon(RAD, T, T2, LAM0, R, M, F, L1, OM, LAM, B, DR, LAMH, BH)
CALL Librations(RAD, LAMH, BH, OM, F, L, L1, L0, B0)
TEMP = L0 / 360
L0 = ((TEMP) - INT(TEMP)) * 360
IF L0 < 0 THEN L0 = L0 + 360
IF L0 <= 90 THEN C0 = 90 - L0 ELSE C0 = 450 - L0
PRINT: PRINT "The selenographic colongitude is "; USING "####"; C0
TEMP = COS(B * RAD) * COS(LAM - LAM0 * RAD)
PSI = ACS(TEMP)
NUM = R * SIN(PSI)
DEN = DR - R * TEMP
I = ATN(NUM / DEN)
IF NUM * DEN < 0 THEN I = I + 3.14159
IF NUM < 0 THEN I = I + 3.14159
K = (1 + COS(I)) / 2
PRINT: PRINT "The illuminated fraction of the Moon is "; USING "#.##"; K: PRINT
INPUT "Latitude of lunar feature "; THETA
INPUT "Longitude                 "; ETA
THETA = THETA * RAD: ETA = ETA * RAD: C0 = C0 * RAD
TEMP = SIN(B0) * SIN(THETA) + COS(B0) * COS(THETA) * SIN(C0 + ETA)
H = ASN(TEMP) / RAD
PRINT: PRINT "Altitude of Sun above feature is "; USING "####"; H: PRINT
END

FUNCTION ACS (X)
ACS = 1.570796 - ASN(X)
END FUNCTION

FUNCTION ASN (X)
ASN = ATN(X / SQR(1 - X * X))
END FUNCTION

SUB Julian (HR, DAY, MN, YR, T)
REM — Enter your time zone below. Set ZONE to 4 if you are on EDT,
REM — 5 if CDT, 6 if MDT, and 7 if PDT. Add one more hour for standard time.
ZONE = 4
DAY = DAY + (HR + ZONE) / 24 + 1 / 1440
IF MN < 3 THEN MN = MN + 12: YR = YR - 1
A = INT(YR / 100): B = 2 - A + INT(A / 4)
C = INT(365.25 * YR): D = INT(30.6001 * (MN + 1))
JD# = B + C + D + DAY + 1720994.5
REM — Calculate the century date
T = (JD# - 2451545) / 36525
END SUB

SUB Sun (RAD, T, T2, L, M, R, LAM0)
T3 = T2 * T
REM — mean longitude of the Sun
L = 280.466 + 36000.8 * T
REM— mean anomaly of the Sun
M = 357.529 + 35999 * T - .0001536 * T2 + T3 / 24490000
M = M * rad
REM —correction for Sun's elliptical orbit
C = (1.915 - .004817 * T - .000014 * T2) * SIN(M) + (.01999 - .000101 * T) *
    SIN(2 * M) + .00029 * SIN(3 * M)
REM — true anomaly of the Sun
V = M + C * RAD
REM — eccentricity of Earth's orbit
E = .01671 - .00004204 * T - .0000001236 * T2
REM — Sun-Earth distance
R = .99972 / (1 + E * COS(V)) * 145980000
REM — true geometric longitude of the Sun
THETA = L + C
REM — apparent longitude of the Sun
OM = 125.04 - 1934.1 * T
LAM0 = THETA - .00569 - .00478 * SIN(OM * RAD)
END SUB

SUB Moon (RAD, T, T2, LAM0, R, M, F, L1, OM, LAM, B, DR, LAMH, BH)
T3 = T * T2
REM — argument of the latitude of the Moon
F = (93.2721 + 483202 * T - .003403 * T2 - T3 / 3526000) * RAD
REM — mean longitude of the Moon
L1 = (218.316 + 481268 * T) * RAD
REM — longitude of the ascending node of Moon's mean orbit
OM = (125.045 - 1934.14 * T + .002071 * T2 + T3 / 450000) * RAD
REM — Moon's mean anomaly
M1 = (134.963 + 477199 * T + .008997 * T2 + T3 / 69700) * RAD
REM — mean elongation of the Moon
D2 = (297.85 + 445267 * T - .00163 * T2 + T3 / 545900) * 2 * RAD
REM — Lunar distance
SUMR = -20954 * COS(M1) - 3699 * COS(D2 - M1) - 2956 * COS(D2)
DR = 385000 + SUMR
REM — geocentric latitude
B = 5.128 * SIN(F) + .2806 * SIN(M1 + F) + .2777 * SIN(M1 - F) + .1732 *
    SIN(D2 - F)
SUML = 6.289 * SIN(M1) + 1.274 * SIN(D2 - M1) + .6583 * SIN(D2) + .2136 *
    SIN(2 * M1) - .1851 * SIN(M) - .1143 * SIN(2 * F)
LAM = L1 + SUML * RAD: DIST = DR / R
LAMH = (LAM0 + 180 + DIST * COS(B) * SIN(LAM0 * RAD - LAM) / RAD) *RAD
BH = DIST * B * RAD
END SUB

SUB Librations (RAD, LAMH, BH, OM, F, L, L1, L0, B0)
REM — inclination of lunar equator
I = 1.54242 * RAD
REM — nutation in longitude, in arcseconds
PSI = -17.2 * SIN(OM) - 1.32 * SIN(2 * L) - .23 * SIN(2 * L1) + .21 * SIN(2 * OM)
PSI = PSI * RAD / 3600
REM — optical librations
W = (LAMH - PSI) - OM
NUM = SIN(W) * COS(BH) * COS(I) - SIN(BH) * SIN(I)
DEN = COS(W) * COS(BH)
A = ATN(NUM / DEN)
IF NUM * DEN < 0 THEN A = A + 3.14159
IF NUM < 0 THEN A = A + 3.14159
L0 = (A - F) / RAD
TEMP = -SIN(W) * COS(BH) * SIN(I) - SIN(BH) * COS(I)
B0 = ASN(TEMP)
END SUB
```

date subroutine using the guidelines in the REM statements. If you prefer to input universal time, the unambiguous system of time reckoning used by astronomers around the world, set ZONE = 0.

In addition to calculating the colongitude, the program also computes the illuminated fraction of the Moon (its phase) at that time. And if desired, you can find the altitude of the Sun above a particular feature's horizon by entering its latitude and longitude. The table on the opposite page gives latitudes and longitudes for some interesting lunar features, and the coordinates of other features can be found in a good lunar atlas, such as Rükl's *Atlas of the Moon*.

You now have a tool that will make lunar observing more rewarding. You'll no longer wonder which features will exhibit the optimal interplay of sunlight and shadow. As long as you own a personal computer, this program will help you zero in on the best lunar targets on any given night. ☐

If you would like to use the program but avoid the drudgery and possible errors of entering it by hand, send a 3.5-inch diskette and a self-addressed, stamped mailer to Lunar Program, ASTRONOMY, P. O. Box 1612, Waukesha, WI 53187. The program is also available by e-mailing a request to bytes@astronomy.com.

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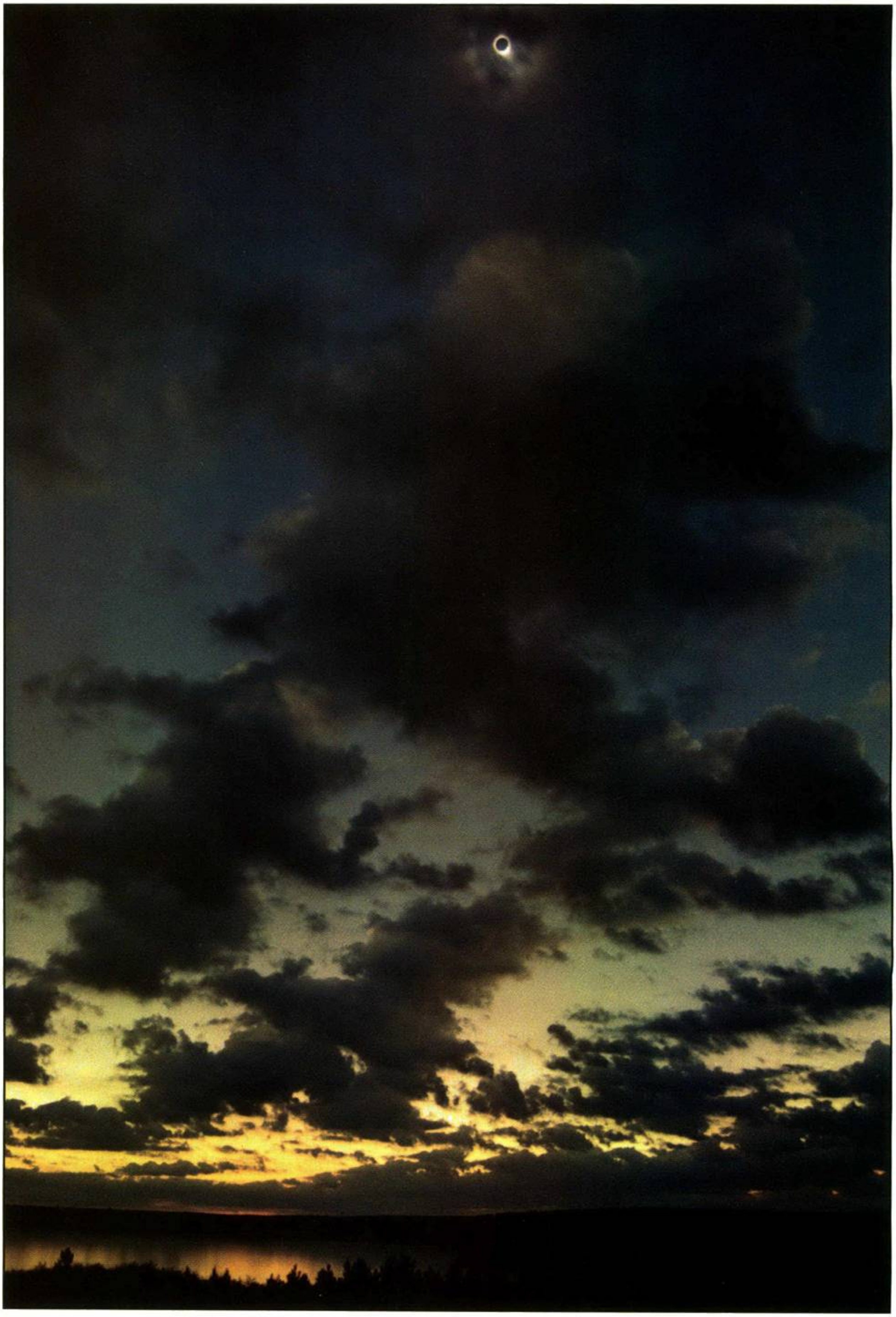

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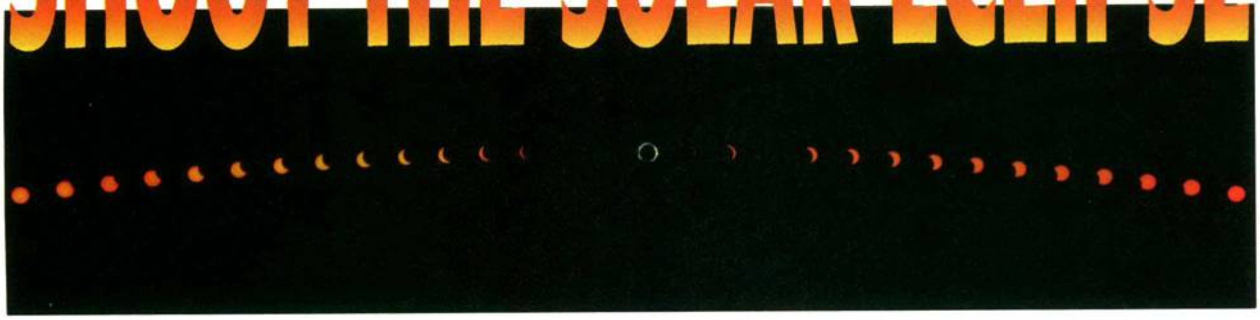
SHOOT THE SOLAR ECLIPSE



Carter Roberts

STUNNING ECLIPSE PHOTOGRAPHY doesn't require a telescope. The entire total solar eclipse of July 11,1991, (below title), was captured using a wide-angle lens fitted to a tripod-mounted camera, firing the shutter every 10 minutes. More than three years later, on November 3, 1994, an eclipse chaser in Argentina landed this surreal view (left) with a 2-second exposure through a 28mm lens. See the Photofacts section for more technical details.

With the right combination of lenses and film, capturing a solar eclipse for posterity is a lot easier than you might think.

by John Shibley

Humans go to great lengths to witness a solar eclipse. Many spend thousands of dollars to travel halfway around the world just to see a few fleeting moments of daytime darkness. Ah, but what wonderful darkness it is! Our Moon's inky-black, seemingly three-dimensional void covers the Sun, which blooms with the regalia of fingerlike prominences and gossamer-thin petals of coronal streamers.

Quite a sight to the eye, but how do you capture such a breathless, otherworldly scene on film? Getting stunning pictures of an eclipse, from when the Moon first touches the Sun's edge on through totality, is much simpler than many other forms of astrophotography. It just requires the right mix of lenses and film. The rest depends entirely on what kind of photo you want.

You can land a stunning eclipse photo with no more than a 50mm lens on a camera mounted on a sturdy tripod. More often than not, eclipses happen in exotic locales. This month's eclipse path, for example, begins in Iran and runs through India and southeast Asia before ending up in the South China Sea (see "Off to See October's Eclipse," July 1995). What better way to capture the unique aspects of an eclipse expedition than to frame the eclipsed Sun within a foreign landscape?

Granted, at 0.5 mm across, the eclipsed disk appears quite small on film. But what sets off this kind of photo is composition. A palm tree, a city's skyline, an ocean vista . . . even the most mundane terrestrial views come alive when framed in the eerie light of totality.

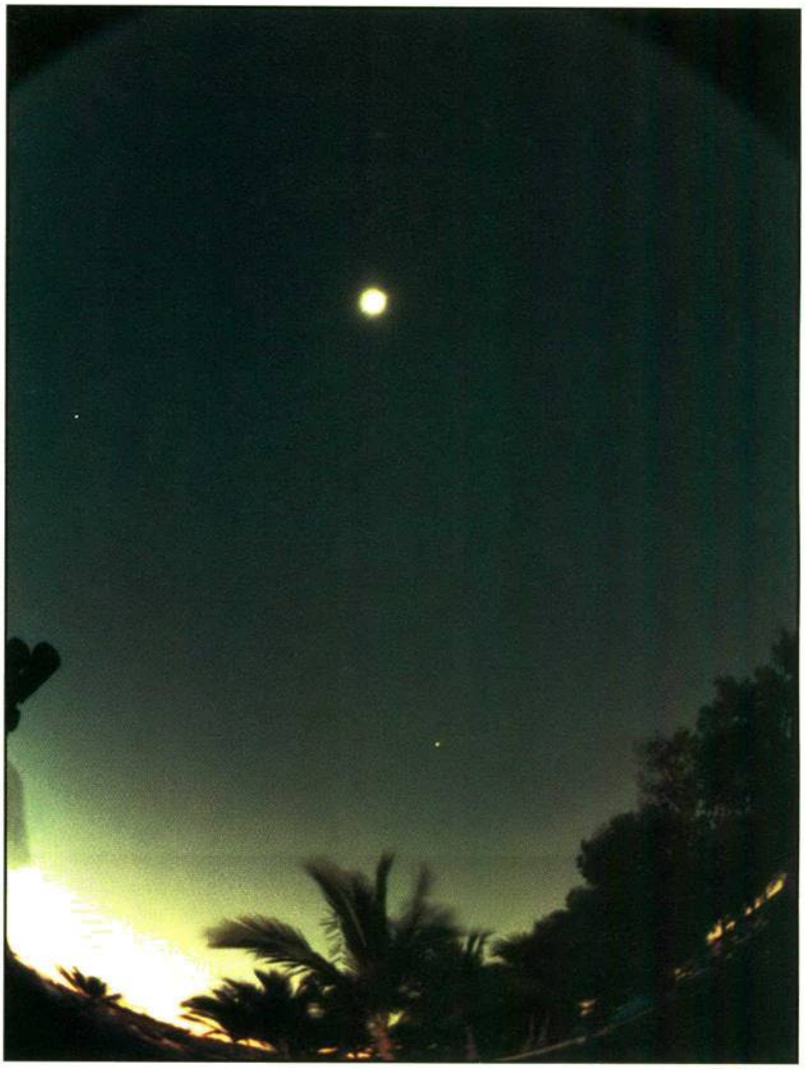
When considering this type of photo, take into account how high the Sun will be at eclipse time. Framing a foreground object is difficult when the Sun's overhead and you're working within the 27° by 40° field of view provided by a 50mm lens on a 35mm camera. A 35mm lens affords a wider field of view — 54° by 38° — but the Sun also appears smaller, a tiny 0.3 mm. For an even wider field of view, think about using a 24mm lens that covers 74° by 53°. Keep in mind, though, that the Sun will appear even smaller.

The bottom line is to check what the Sun's elevation will be at mid-eclipse from your observing location. (You can do this before an eclipse trip by running any planetarium-type program on a home computer, or by checking your library for NASA's *Fifty-year Canon of Solar Eclipses*, reference publication 1178, revised.) Then a day or two before the eclipse, scout out an appropriate site for interesting foreground objects.

If the Sun lies too high from your site, don't give up on those wider lenses yet. During totality the sky grows dark enough to glimpse not only bright planets, but many stars as well. This month's eclipse finds Mercury and the star Spica west of the Sun some 17° and 7°, respectively. To the east, at 17° and 32°, lie Venus and Mars, while 31° to the north is the orange star Arcturus. Capturing these targets on film adds even more atmosphere to an already magnificent celestial scene.

Whether framing a terrestrial vista or shooting straight overhead, try bracketing your exposures on moderate-speed film between one and ten seconds. Don't worry about overexposing the tiny solar corona. You are trying to record the subtle colors of twilight and

BRIGHT STARS AND PLANETS SHINE during the false twilight of an eclipse. An extreme wide-angle view during the 1991 total eclipse in Baja takes in Venus, to the lower left of the over-exposed corona; just above the trees is Sirius.



David Nelson

eerie lighting on the landscape, along with some bright stars and planets.

If it's close-ups of the Sun's corona you want during totality, use a long focal length telephoto lens between 300mm and 600mm. To figure out how big the Sun will be on your film, divide the telephoto's focal length by 110. For example, a 600mm lens will yield a 5½-mm-wide image.

If you don't have a lens that long, consider using a 2X or 3X teleconverter. These accessories, though, add another layer of glass the light has to go through, which will lengthen your exposures and may possibly degrade image quality.

With any kind of higher magnification photography, it's doubly important to mount the camera on a rock-steady tripod. Set up away from crowds, where errant feet might bump the tripod. Also be on the lookout for camera-related vibrations. Every time the camera's shutter is released, a mirror flips out of the way to allow light to strike the film. This slapping sets up unwanted vibrations. If your camera has a mirror lock-up feature, use it before releasing the shutter. Another source of vibration might come from your firing the camera. To keep this at a minimum, use an air-bulb cable release or the camera's self-timer feature.

For detailed shots of the Sun's corona and red prominences you'll need optics in the 750mm to 2,000mm range . . . a telescope. You don't need a big telescope here; a 3 or 4-inch scope with a focal length of 1,000mm will work just fine.

At higher magnifications, blurriness due to the Sun's motion through the sky might pose a problem. To calculate the longest exposure possible before motion blurriness starts to show, divide the telescope or telephoto's focal length into 250. For example, a 1,000mm focal length telescope starts to show some trailing blurriness after 1/4 second (250÷1,000 = 1/4).

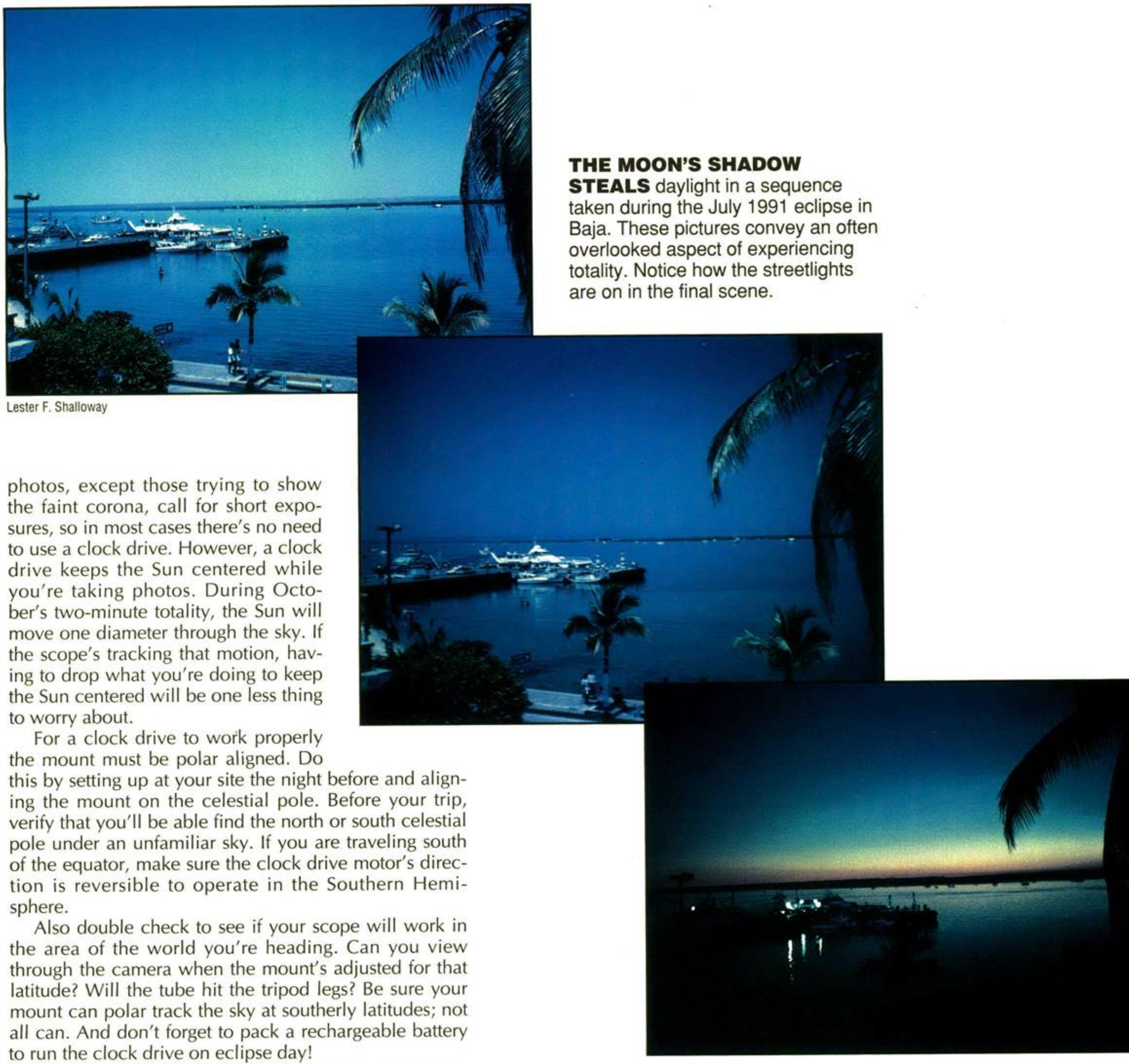
A clock-driven telescope mount allows for longer exposures. It's true that most eclipse

Eclipse Exposures for ISO 100 film

At . . .	**f/4**	**f/5.6**	**f/8**	**f/11**	**f/16**
Partial Phases	1/500	1/250	1/125	1/60	1/30
Diamond Ring	1/2000	1/1000	1/500	1/250	1/125
Prominences	1/1000	1/500	1/250	1/125	1/60
Inner Corona	1/250	1/125	1/60	1/30	1/15
Outer Corona	1/15	1/8	1/4	1/2	1 second

For ISO 25 film, lengthen shutter speeds by two increments (for example, 1/500 becomes 1/125). For ISO 200 films, shorten exposure times by a factor of two (1/125 becomes 1/250).

Always use a proper solar filter over the aperture of your lens or telescope when shooting partial phases.



THE MOON'S SHADOW STEALS daylight in a sequence taken during the July 1991 eclipse in Baja. These pictures convey an often overlooked aspect of experiencing totality. Notice how the streetlights are on in the final scene.

Lester F. Shalloway

photos, except those trying to show the faint corona, call for short exposures, so in most cases there's no need to use a clock drive. However, a clock drive keeps the Sun centered while you're taking photos. During October's two-minute totality, the Sun will move one diameter through the sky. If the scope's tracking that motion, having to drop what you're doing to keep the Sun centered will be one less thing to worry about.

For a clock drive to work properly the mount must be polar aligned. Do this by setting up at your site the night before and aligning the mount on the celestial pole. Before your trip, verify that you'll be able find the north or south celestial pole under an unfamiliar sky. If you are traveling south of the equator, make sure the clock drive motor's direction is reversible to operate in the Southern Hemisphere.

Also double check to see if your scope will work in the area of the world you're heading. Can you view through the camera when the mount's adjusted for that latitude? Will the tube hit the tripod legs? Be sure your mount can polar track the sky at southerly latitudes; not all can. And don't forget to pack a rechargeable battery to run the clock drive on eclipse day!

Another potential obstacle to taking first-rate eclipse photos is poor focusing. Getting sharp images with a lens is easy: focus to infinity. With a scope, however, you must focus directly on the object being shot.

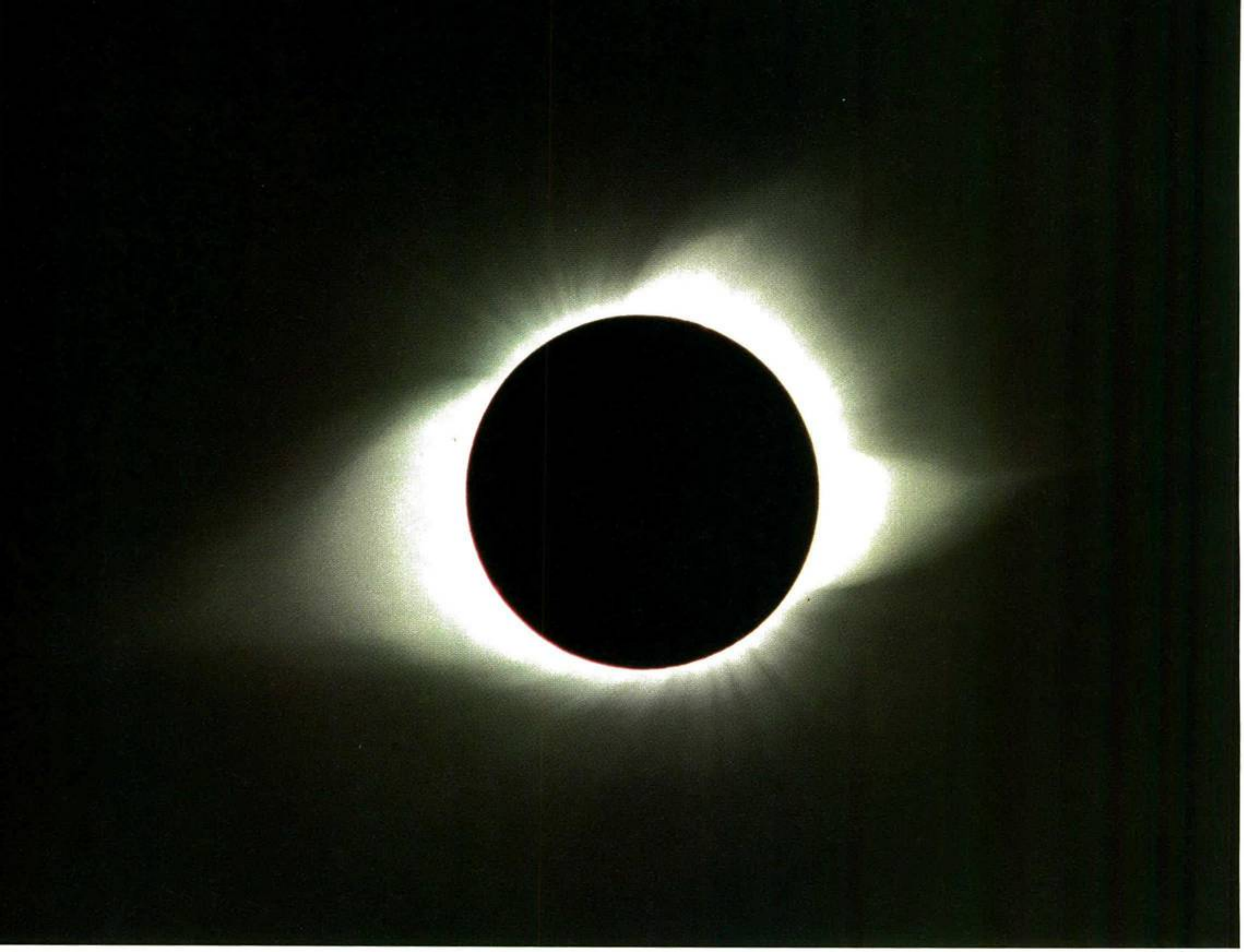
During totality the easiest features to focus on are bright solar prominences. Remember to pause between exposures and verify maximum sharpness. One accessory, a bright, fine-grained focusing screen, makes critical focusing easier. If your camera has an interchangeable focusing screen feature, install a screen designed for high-magnification photography.

After you've settled on what kind of picture you want to take and the lens array you'll use, it's time to select the best film. Here's where many people make a wrong assumption.

Conventional wisdom might tell you that since the Sun gets covered during an eclipse and the sky darkens, you'll want to use a faster, high-speed film. But the truth is that most features seen during a total solar eclipse, the prominences and the corona, for example, are surprisingly bright. Knowing this, experienced eclipse photographers settle on films with speeds around ISO 100. Such films are less grainy, record a wider range of contrast, and saturate with richer colors. All these factors add up to a more pleasing eclipse picture.

The only time a faster film might work better is when you're shooting from the deck of a rolling ship. Faster films allow faster shutter speeds, which in turn counter any motion blurriness caused by ocean swells.

Another fear people have is getting all their exposures



Dan Schechter

as accurate as possible. Relax! If you shoot a variety of exposure settings, there's no way *not* to get a good eclipse picture. Faster exposures will record just the brilliant red prominences and the inner corona, while longer times will pick up faint, outer coronal streamers. In a nutshell, bracket through an array of times and remember that most, if not all, of the pictures you take will be usable.

As the eclipse progresses, however, there are standard exposure values around that you can bracket for optimum results (see the table on page 76).

In the few seconds before and after totality, sunlight glistens between valleys on the Moon's limb. This creates the striking "diamond ring" effect or a string of glimmerings called Baily's beads. Shutter speeds of between 1/1000 and 1/125 of a second work best to capture this dramatic aspect of the eclipse.

When the Moon completely covers the Sun, go for bright prominences by bracketing between 1/30 and 1/500 of a second. At mid-totality, lengthen this range to 1/8-second to a maximum of one second. These pictures record the Sun's corona, which is somewhat fainter than prominences.

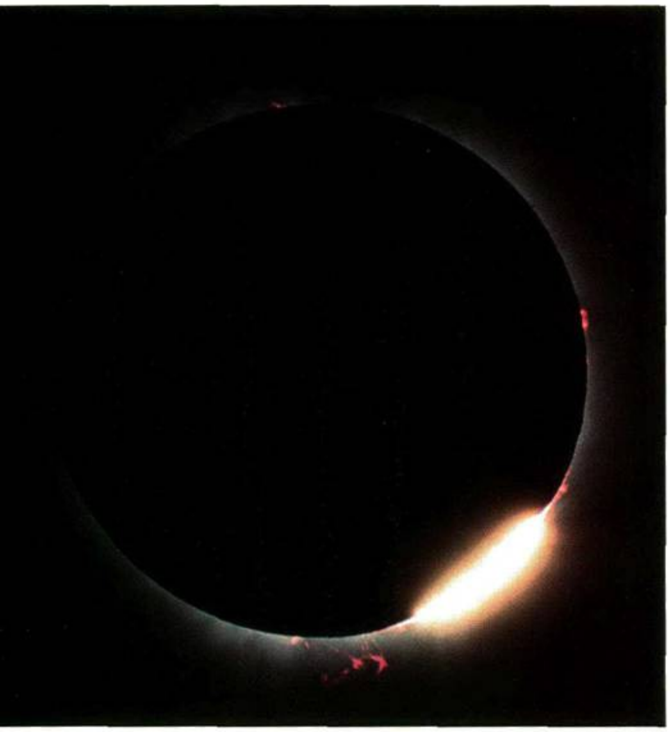
Good starting points for scenic wide-angle photos during mid-eclipse range between 1/4 and 12 seconds, with f-stops between f/2.8 and f/4. For telephoto shots of the Sun at totality, work between 1/100 and 1/8 of a second between f/4 and f/5.6.

To determine proper exposures through a telescope, you first must know its focal ratio. This number should be marked somewhere on the instrument. If it isn't, just divide the scope's focal length by the diameter of its lens or mirror. Thus a 5-inch scope (125mm aperture) with a 1,250mm focal length is an f/10 instrument (1,250÷125 = f/10).

After you've determined your system's f/ratio, cross-reference it with the accompanying table. For the most part, f/10 and f/11 scopes dictate exposures that range from 1/500 to 1/2 of a second. Scopes with faster f-ratios, f/4 to f/8, can accommodate faster shutter speeds, while slow scopes (f/16 or more) require longer exposures.

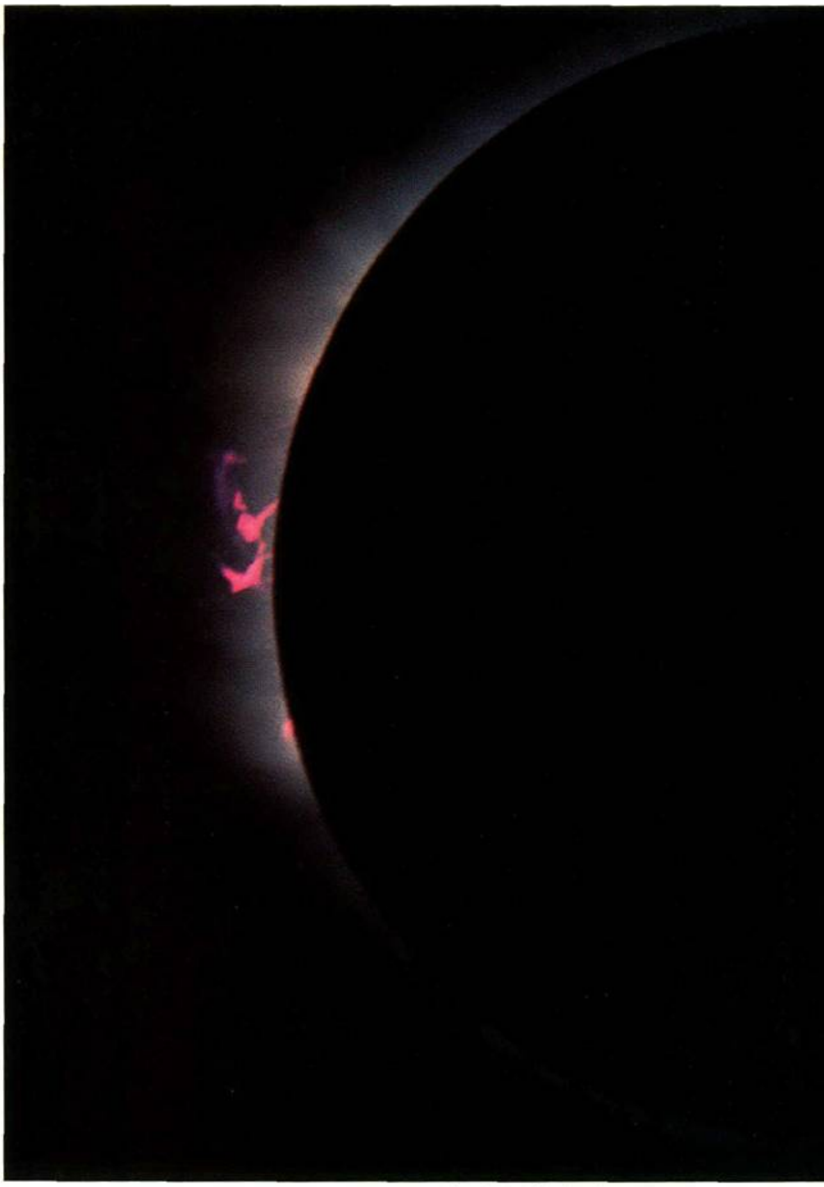
Obviously the high point of a solar eclipse is totality itself, but capturing a series of partial phases on film can also be rewarding. Even though it's perfectly safe to aim your scope or camera lens directly at the Sun during totality, you'll need safe metal-on-glass or mylar-type solar filters to view or shoot the Sun when it's not completely covered by the Moon. Such filters slide over the front of the telescope or lens and block nearly all of the Sun's visible light, as well as all of its ultraviolet and infrared radiation. Companies that sell these filters are listed as advertisers elsewhere in the magazine.

In a pinch a #14 welder's glass, available from any welder's supply shop for around $5, will work well for



Roland and Marjorie Christen

SHORT EXPOSURES DURING TOTALITY snatch brighter details, like this 1/125-second exposure (above) that caught prominences, the Diamond Ring, and the Sun's bright inner corona. Stunningly delicate structure in the fainter, outer corona require at least 1-second exposures (left).



Shepherd & Shepherd

CLOSE-UP PHOTOS reveal solar prominences arcing off the Sun's surface (above). To boost magnification, try coupling a 2x teleconverter to the telescope or projecting the image with an eyepiece.

viewing and photography. Though these filters make the Sun look green and are not optically perfect, they will yield acceptable images when taped securely to the front of a short telephoto lens (100mm to 400mm).

Other filters might appear appropriate, but they don't block the Sun's harmful — and invisible — ultraviolet and infrared rays. These include cross polarizers, neutral density filters, and stacked layers of fogged film. Working with these filters courts disaster for your eyesight.

One type of photography uses a mix of filtered and unfiltered photography. It involves shooting multiple exposures on a single frame. If your camera has a multiple-exposure feature, it might be a shot worth considering.

With the camera set upon a sturdy tripod, expose the film every ten minutes through a solar filter during partial phases. With ISO 100 film, shoot at 1/125 of a second with the lens set to f/8. During totality, slip the filter off and take a single 1-second exposure, then replace the filter to shoot the eclipse's waning phases.

All told, the Sun moves about 45° during an entire eclipse, which means you'll need to use a 35mm lens to capture the entire sequence. If you're outside the central path, do the series with the filter in place, ending with an unfiltered shot of your observing site.

Planning such a picture might require you to make a quick trip to the site the day before to note the Sun's position relative to a few foreground objects. The downside to this photo is that the whole eclipse is on one frame of film. One bump, one error in exposure or timing could ruin the whole exposure. With that in mind, you might even devote a second camera to this type of shot.

Regardless of whether you embark on multiple exposures or just stick to the simpler routine of shooting at totality, you're in for the experience of your life. And that's the key word to any eclipse chase: experience. Don't get so caught up in shooting the spectacle that you don't enjoy it. After going through the trouble of traveling to an eclipse's centerline, you owe it to yourself just to soak it in for at least a few seconds. After all, eclipse memories are what will make all those wonderful pictures come alive for many years to come. ☐

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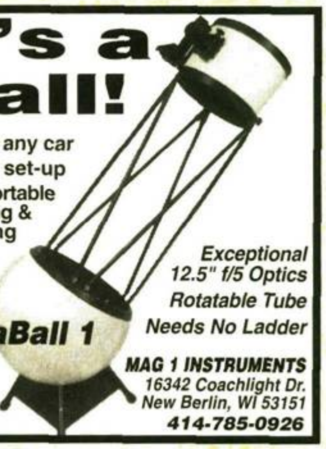

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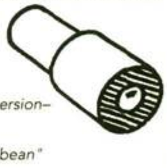

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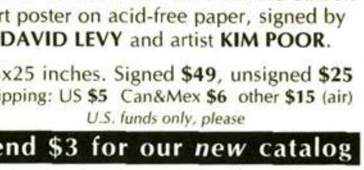

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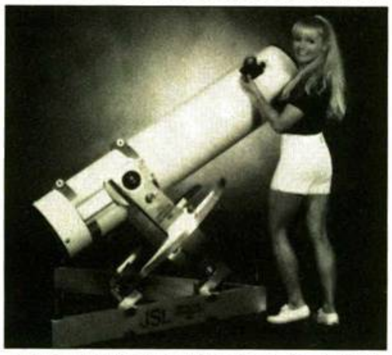

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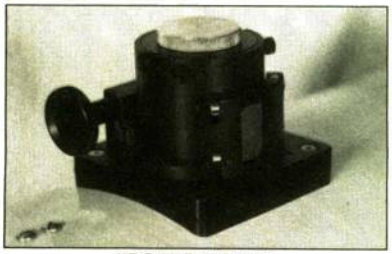

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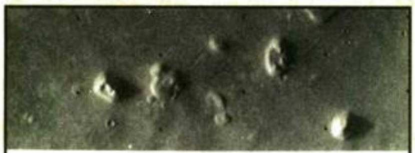

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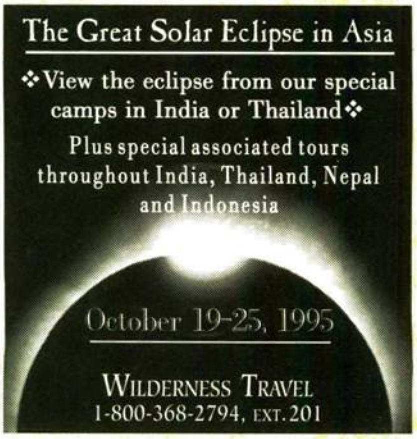

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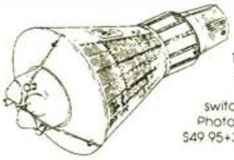

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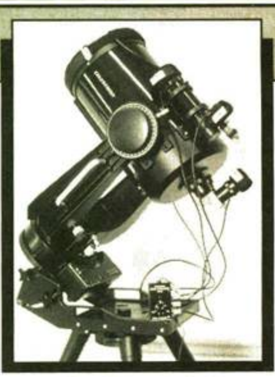

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3.1"	52.00	3.1"	42.00
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4-1/4" to 5"	74.00	4-1/4" to 5"	64.00
6"	79.00	6"	69.00
8"	95.00	8"	85.00
10"	109.00	10"	99.00
11"	119.00	11"	109.00
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14"	169.00	14"	149.00

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3.5" to 4"	76.00	3.5 to 4"	66.00
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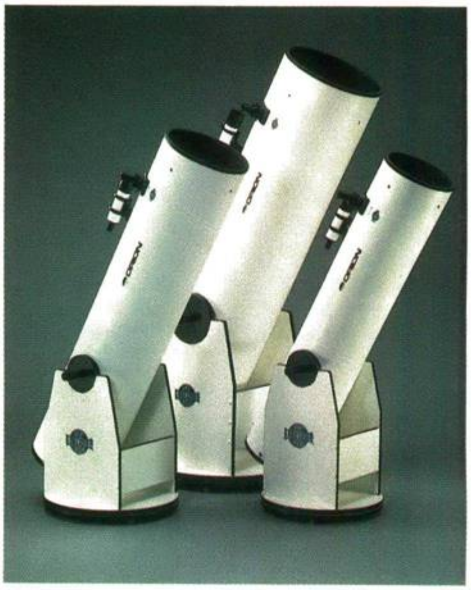

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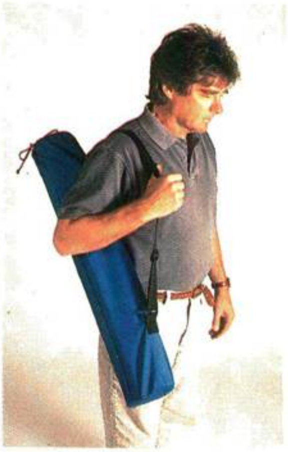

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This department presents announcements issued by manufacturers. Product information is as supplied by the manufacturers or distributors. All prices are suggested retail. Suppliers should send announcements and color photographs of their products to the attention of John Shibley, P.O. Box 1612, Waukesha, WI 53187, or newprod@astronomy.com.

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Sehgal Corporation, 1776 Windflower Way, Glouchester, Ontario K1C 5Y9, (613) 794-1134; fax, (613) 837-3011. Homeyer FM Flip Mirror Previewer: $399(US); Homeyer FW Filter Wheel: $399 (US); Homeyer FMFW2 Combination Filter Wheel/ Previewer: $599 (US).

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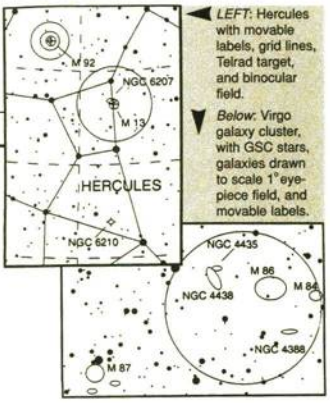

LEFT: Hercules with movable labels, grid lines, Telrad target, and binocular field.

Below: Virgo galaxy cluster, with GSC stars, galaxies drawn to scale 1° eyepiece field, and movable labels.

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Explorer of the Cosmos

Edwin Hubble, Mariner of the Nebulae

Gale E. Christianson (Farrar, Straus & Giroux, 1995), ISBN 0-374-14660-8, 432 pages, hardcover, $25.

Edwin Hubble really is a man you ought to meet. Most people associate his name with Hubble Space Telescope, an Earth-orbiting observatory named in his honor and launched in April 1990. But long before the epochal HST, there was Edwin Hubble the man, who, like his namesake is doing today, transformed the way we looked at the vast universe around us.

Who was Edwin Hubble? Surprisingly, *Mariner of the Nebulae* is the first full-length biography to answer that question. Biographical entries will tell you Hubble was the first to garner proof that "spiral nebulae" were not star-systems-in-the-making in our own galaxy, but "island universes," galaxies in their own right. Hubble was also the first to use variable stars to plumb a distance to the nearest spiral galaxy, M31, in the constellation of Andromeda. While studying this and other galaxies, he formulated a classification scheme still used today that groups galaxies by shape. Hubble also scrutinized the brightest members of galaxy clusters to estimate their distance.

In the late 1920s, he studied galaxy spectra and determined that the farther a galaxy is from Earth, the faster it appears to be moving away, or receding, from us. He had stumbled onto the concept that we live in an expanding universe.

Beyond all this, who was Edwin Hubble? In a lively and very readable way, author Gale E. Christianson shares all Hubble with us through the writings and recollections of Hubble, his friends, family, and colleagues, right down to those working as night assistants at Mt. Wilson observatory in California.

Hubble was born by lamplight in rural 1889 Missouri, the second of seven children born to a middle-class lawyer employed as an insurance adjuster. Young Hubble progressed through prep school and into the University of Chicago, distinguishing himself as much as an athlete as a gifted student. Despite getting a bachelors in mathematics and astronomy from Chicago in 1910, Hubble followed his family's wishes and accepted a Rhodes scholarship to study law at Oxford.

But his first love was the night sky, and after practicing law for a year, Hubble applied himself to astronomy and landed a Ph.D. in 1917. The universe, however, would have to wait for World War One; Hubble enlisted as an Army private and shipped out to France. His appearance on Mt. Wilson after the war ended in 1919 coincided with the inauguration of the 100-inch Hooker telescope, the HST of its time. Fate had matched the right man with the right technology at the right moment in time.

Besides detailing the science and history of Hubble's life and times, Christianson's imagery makes *Mariner of the Nebulae* shine. There's the Mt. Wilson night assistant's recollection of Hubble silhouetted against a night sky, guiding the 100-inch during an hour-long exposure. Hubble is clad in an army-issue wool trench coat that billows in the brisk night breeze, the cold wind blowing embers from his pipe is all directions around the observatory as he reconstructs old cowboy songs and sentimental ballads out loud.

With anecdotes like these, Hubble lives again in Christianson's book, becoming more than just another notable from history. He's a person much like you and I, with an insatiable love for the cosmos and an unquenchable thirst for knowledge. Once you've read *Mariner of the Nebulae*, you'll understand why a subsequent generation of Hubble's contemporaries felt compelled to name a great, orbiting observatory after him. — *John Shibley*

Review the first chapter and table of contents of Mariner of the Nebulae *on the Internet at: http://dab.psi.net/chapterone/astronomy*

More New Books

Spaceflight: A Smithsonian Guide

Valerie Neal, Cathleen S. Lewis, and Frank H. Winter, (Macmillan, 1995), ISBN 0-02-860007-X, 256 pages, clothbound, $24.95, paper, $18.00.

This spanking new volume provides a broad overview of the history of space exploration. The authors, three curators at Smithsonian's National Air and Space Museum in Washington, arranged the book in a rough chronological sequence.

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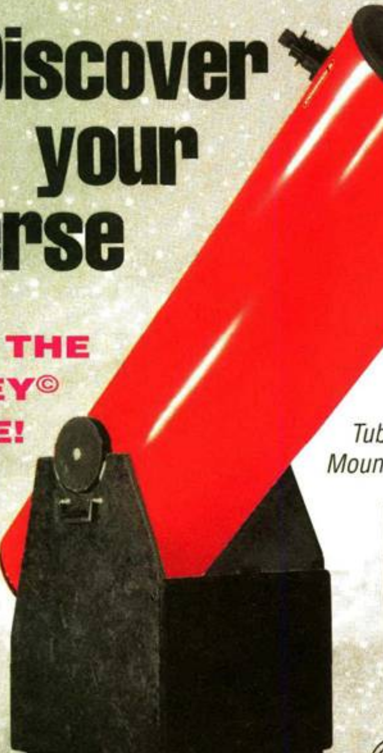

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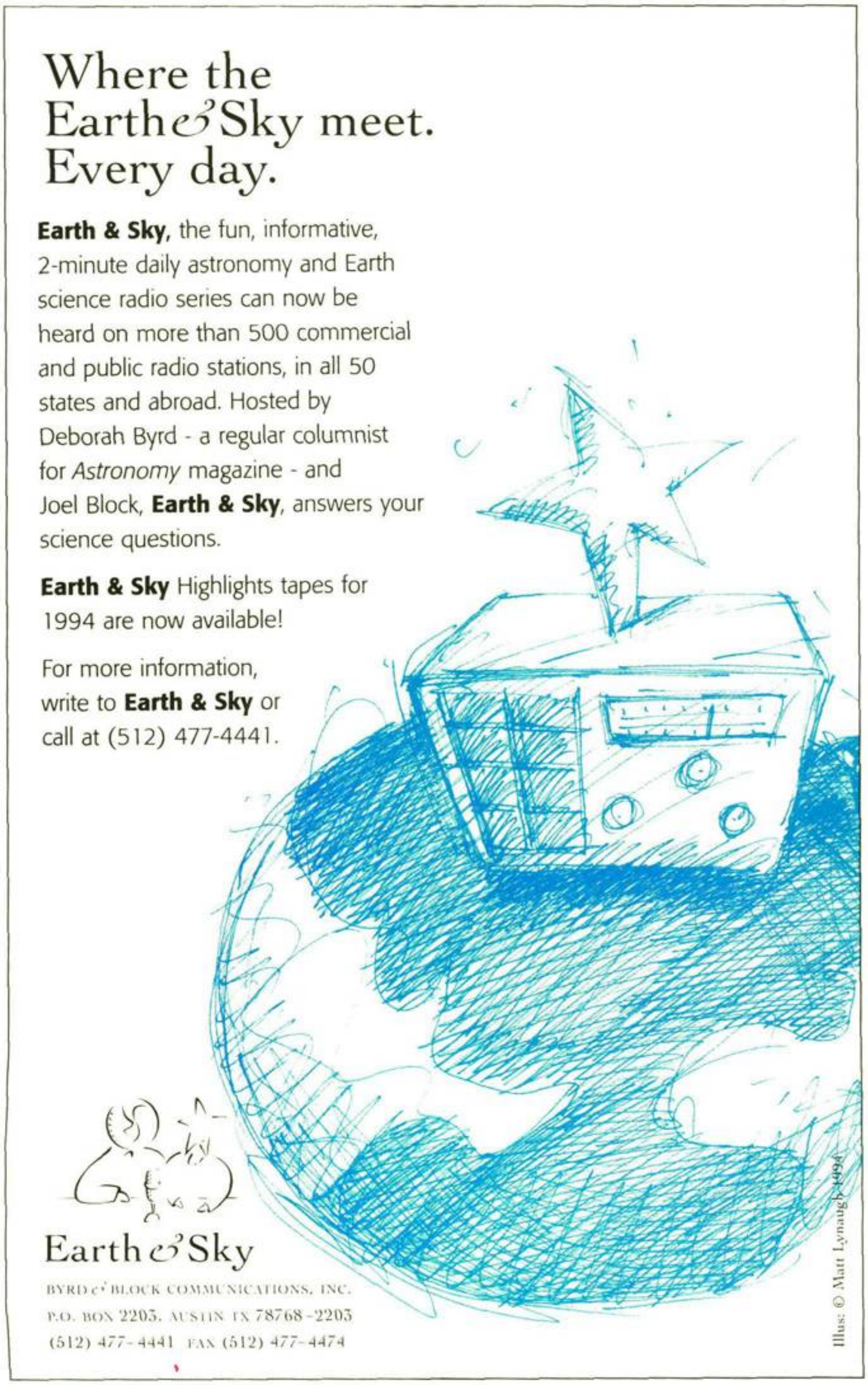
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from weightlessness to propulsion to flight trajectories. It quickly moves to the pioneers of rocketry: Tsiolkovsky, Goddard, von Braun, and others. After a chapter on the rockets themselves, it swiftly moves to a broad chapter that covers the manned and unmanned missions of the United States and Soviet Union from the early Cold War days to the most recent programs, Mir and the Space Shuttle. Next is the obligatory chapter on Apollo, which is followed by a chapter on the robotic missions to the planets. The final chapter discusses Earth-orbiting satellites used for communication, meteorology, remote sensing, and astronomy.

The publishers clearly intend this to be a highly accessible reference source. The top of each page is color-coded by chapter. The book is lavishly illustrated with more than 350 color photographs and diagrams. A 25-page glossary includes short biographies and definitions in alphabetical order. A fold-out attached to the back cover compares rocket sizes on one side, and lists important milestones in the history of spaceflight on the other. The book also has a list of all piloted space missions, from Yuri Gagarin's 1961 flight up to the December 1993 shuttle mission. Rather than provide in-depth analysis, the authors opt for broad coverage of history and topics. The book, which is part of a Smithsonian-Macmillan series exploring science, technology, and history, is perfect for those who need to quickly look up facts on space exploration.

Who's Who On the Moon: A Biographical Dictionary of Lunar Nomenclature

Elijah E. Cocks and Josiah C. Cocks, (Tudor Publishers Inc., Greensboro, NC, 1995), ISBN 0-936389-27-3, 599 pages, clothbound, $45.00.

Here is a perfect reference tool for hardcore lunar observers. This unique volume contains nearly 1,600 concise biographies of all the men and women who have received the honor of having lunar features named after them, from Ernest K. Abbe to Richard Adolf Zsigmondy. The latitude, longitude, and diameter of each feature (almost all are craters) is included with each entry. Appendices list the names by nationality, occupation, feature size, and feature location. The book also includes photographs of both the near side and far side of the Moon, as well as the north and south polar regions. ☐

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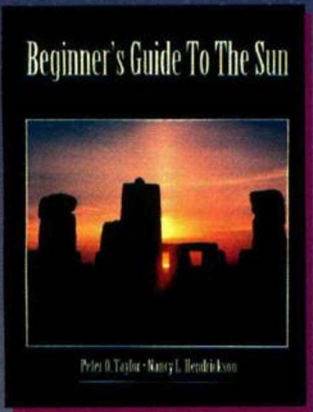
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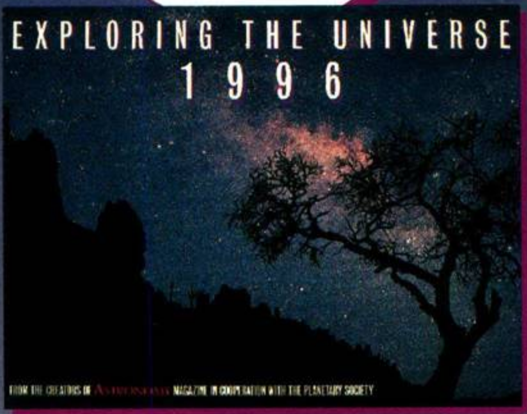
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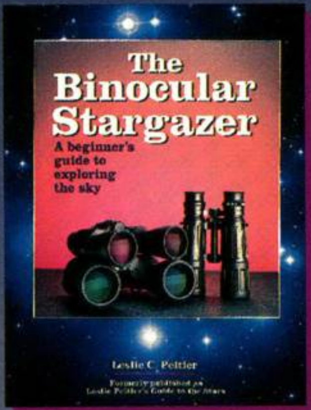
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Black holes, black dwarfs, black bodies — the terminology of astronomy is potentially confusing. Most armchair astronomers have survived by keeping an astronomical encyclopedia or dictionary, or both, by their reading chair. But with astronomical research expanding into X rays, gamma rays, neutrinos, quarks, and the nether regions of general relativity, a reader's bookshelf of ready references has had to expand as well, into the fields of high-energy physics, nuclear physics, and other esoteric areas of science.

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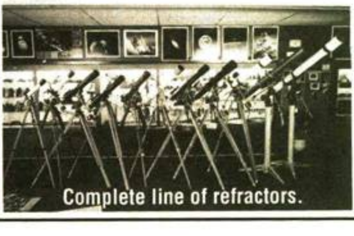

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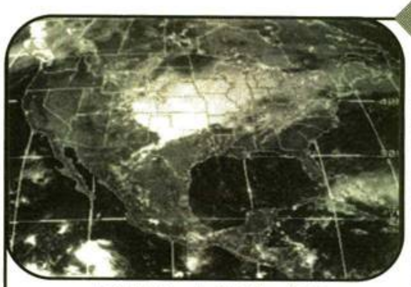

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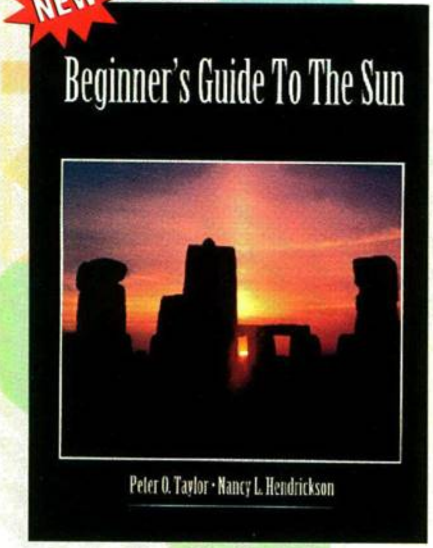
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Peter O. Taylor · Nancy L. Hendrickson

Beginner's Guide to the Sun tells you how to look directly at the Sun without hurting your eyes. In plain English the authors reveal the secrets of the Sun—from its earliest significance to primitive priests and astronomers to the amazing cycles of sunspots, eclipses, massive energy outbursts and size fluctuations we can observe today. Readers will even learn how to perform their own solar experiments at home and come up with actual scientific data. By Peter O. Taylor & Nancy L. Hendrickson. 7⅜ x 9⅞; 160 pgs.; 16 color and 80 b&w photos; perfect-bound softcover.
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the design and testing of optics such as telescopes. A user can click and drag a lens or mirror anywhere on the screen using a mouse. Rays representing the path of light shoot through the lens, focusing at the image plane. Users can select different colors of light to check that they all focus in the same spot.

For optical elements, this version of *Optics Lab* includes simple concave and convex lenses and mirrors and adds aspheric elements such as Schmidt corrector plates used in Schmidt-Cassegrain reflectors and conic sections used in other types of reflecting telescopes. Users have at their disposal several analysis tools, such as wavefronts and point spread functions, so they can determine field curvature, image distortion, and the amount of stray light in the field. An optimization process tweaks designs to produce the best images.

Apochromat designers will rejoice in the tables containing over 250 types of glass. They can search these tables by refractive index or dispersion and add new optical glasses as they become available. To help new users get started, the program includes many examples of telescope designs.

CD-ROMs

WeMake CDs (P.O. Box 20158, Indianapolis, IN 46220) offers *Visions of Saturn* (volumes 1 and 2) for $30 each. The CD-ROMs contain several thousand images of Saturn, its rings, and its satellites in GIF file format with text files describing each image. The disks include DOS and Windows versions of shareware programs to view the images.

Nick Marella (826 Northwood Avenue, Cherry Hill, NJ 08002, (800) 292-1414) offers CD-ROMs containing images of Mars, Venus, Jupiter, Saturn, Uranus, Neptune, and the satellites of the outer planets. *The Mars and Venus CD* ($24.95) holds more than 600 images of Earth's neighboring planets, taken by the Viking Orbiter and Magellan spacecraft. *Voyager Moons* ($29.95) contains 600 images of the outer planets and their satellites taken by the Voyager spacecraft. The disks require Windows and its Paintbrush program to display the BMP-formatted images or an image viewing program. ☐

Software developers may send copies of new programs to AstroBytes, ASTRONOMY Magazine, P.O. 1612, Waukesha, WI 53187 or e-mail bytes@astronomy.com.

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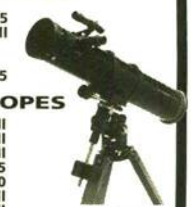

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October 13-14
Imaging the Sky '95, Oregon. Contact Jim Girard, (503) 643-1813, 72317.3442@compuserve.com.

October 13-14
Starfest '95, Tennessee. Contact Adam Thanz, Bays Mountain Park, 853 Bays Mountain Park Road, Kingsport, TN 37660.

October 19-22
Deep South Regional Stargaze, Mississippi. Contact Barry Simon, 820 Emerald Street, New Orleans, LA 70124.

October 20-22
Astronomy Jamboree, New York. Contact the Custer Institute, (516) 765-2626, custerdude@aol.com.

October 20-21
Fall Central Texas Star Party, Texas. Contact the AAS, P.O. Box 12831, Austin, TX 78711-2831.

October 20-22
Stella-Della-Valley IX, Pennsylvania. Contact Ed Melnick, 1443 Devon Road, Warminster, PA 18974.

October 21-22
All Arizona Star Party, Arizona. Contact Don Wrigley, 423 W. 5th Avenue, Apache Junction, AZ 85220.

October 21
Blue Ridge Parkway Regional Stargaze, Part II, North Carolina. Contact Greg Kirby, 5026 Poplar View Lane, Granite Falls, NC 28630.

October 24-29
Okie-Tex Star Party, Oklahoma. Contact Beryl Cadle, 6616 N.W. 20th Street, Bethany, OK 73008.

October 27-30
Convention of the Antique Telescope Society, Pennsylvania. Contact Walter H. Breyer, 30 Green Valley Road, Wallingford, PA 19086.

October 27-29
Blackwater Falls Astronomy Weekend, West Virginia. Contact Ron Cockeram, 5216 Bailey Road, Cross Lanes, WV 25313. ☐

READINGS & PHOTOFACTS

A Milestone in Fornax (page 42)
The Light at the Edge of the Universe, by Michael D. Lemonick (Princeton University Press, 1993). An up-to-date account of cosmology by the science writer for *Time*.

Cyberspace (page 48)
The Internet for Scientists and Engineers, by Brian J. Thomas, (SPIE Press, P.O. Box 10, Bellingham, WA 98227-0010, (360) 676-3290, 1994). Describes resources on the Internet of interest to amateur and professional scientists.

Sunrise on the Moon (page 76)
The Moon: An Observing Guide for Backyard Telescopes, by Michael T. Kitt, (Kalmbach Books, 1992). Describes how to observe lunar features and those best seen near the terminator.

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p. 5: Wallace Baldwin; **p. 5:** Jim Baumgardt; **p. 34:** James M. Baker and Dennis Milon; **pp. 38-39:** James R. Foster; **pp. 40-41:** Luke Dodd; **p. 62:** Wallace Baldwin; **p. 63:** Seth Horowitz; **p. 65:** Terry Atwood; **p. 66:** George Livadaras; **p. 68:** Jim Baumgardt; **p. 69:** Jean Dragesco; **p. 70:** Derek Robson; **p. 71, left:** Bill Wilkinson; **right:** Yuh-Tsuen-Li; **p. 74:** Mike Branick; **p. 75:** Carter Roberts; **p. 76:** David Nelson; **p. 77:** Lester F. Shalloway; **p. 78:** Dan Schecter; **p. 79, left:** Roland and Marjorie Christen; **right:** Shepherd & Shepherd; **p. 108:** Luke Dodd; **p. 109, top:** Alberto Levy, 8-inch f/10 SCT, Fujichrome Provia 100 film, 1/30-second exposure; **bottom left:** Jim Manning, 600mm lens, Ektachrome 100 film, 1/2-second exposure; **bottom right:** Olivier R. Staiger, 300mm lens at f/5.6, Kodachrome 64 film; **p. 110, top:** Pierre Guillermier, 4-inch refractor at f/10, composite of five exposures of 1/15 second to 1 second; **bottom:** Karl W. Bornhoeft, 50mm lens, 1000 ISO film; **p. 111, top:** Michael Stecker, 8-inch Maksutov-Newtonian reflector, hypersensitized Fuji Super HG 400 film, composite of two 45-minute exposures; **bottom left:** Martin C. Germano, 14.5-inch f/5 reflector, hypersensitized Tech Pan film, 105-minute exposure; **bottom right:** H.J.P. Arnold, 7-inch f/9 refractor, Tech Pan film, Daystar 0.6Å hydrogen-alpha filter, digitally enhanced; **p. 112:** Pierre Guillermier, 50mm lens at f/2.8, Kodachrome 25 film, 1-second exposure (foreground image), 4-inch refractor at f/10, Kodachrome 25 film for partial phases and Fujichrome 200 for totality (Sun image). ☐

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Luke Dodd

BIG ON CELESTIAL PHOTOGRAPHY A 35mm camera can deliver stunning results, but wait till you see what a large-format camera can do.

RELATIVITY ON TRIAL An otherwise normal binary star named DI Herculis raises profound questions about Einstein's theory of general relativity.

NASA'S BRAVE NEW WORLD The Discovery program promises more and better science with fewer dollars. Here's the latest on the exciting missions ahead.

TO THE EDGE OF THE UNIVERSE The microwave background forms an impenetrable curtain for normal light, but astronomers hope one day to "see" beyond with neutrinos and gravitons.

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READER REPORTS

An Incredible Night on Fremont Peak

David Kutilek of San Bruno, California, found his thrill on Fremont Peak. It was Saturday, February 18, 1995, the air was a warm 60° F, the sky dark, and the wind calm. On top of Fremont, the only thing in David's mind, and those of his fellow members of the San Mateo Astronomical Society, was to find the Horsehead Nebula. "Even though the Moon was approaching First Quarter," says Kutilek, "I knew it would set about 11 p.m., leaving the sky wide open for deep-sky viewing."

Kutilek drove down California 101 toward the peak and, as he closed in, the weather turned somewhat foggy and hazy. When he reached San Juan Bautista, the fog thickened, but Kutilek hoped for the best. "Sure enough, once I was halfway up the hill, the sky just lit up like a Christmas tree," he says. "It just blew me away."

Kutilek used his parking lights to illuminate his telescope, a 9-inch reflector, as he set it up. "I wanted to see the Horsehead with my own eyes," says Kutilek, "with real photons bouncing into my sockets — not on some CCD frame or film." To kill time as the Moon slowly sank, he scoped out lunar crater formations, the Orion Nebula, some clusters in Auriga, and a few other deep-sky objects.

Then, in the still darkness of the night, Kutilek stuck a 32mm eyepiece with an HB filter in the focusing tube and aimed smack on the Horsehead field. Nothing. "So I tried lower power," he says, "my widest field of view, which amounted to 55'." In an instant, he spotted a faint

The Partial Lunar Eclipse of April 15, 1995

by Alberto Levy
(8-inch f/10 SCT, Fujichrome Provia 100 film, 1/30-second exposure on April 15, 1995, from San Diego, California)

Eclipsed Moon over the Mountains

by Jim Manning
(600mm lens, Ektachrome 100 film, ½-second exposure on April 15, 1995, from near Bozeman, Montana)

Annular Eclipse over Ecuador

by Olivier R. Staiger
(300mm lens at f/5.6, Kodachrome 64 film, taken on April 29, 1995, from Macara, Ecuador)

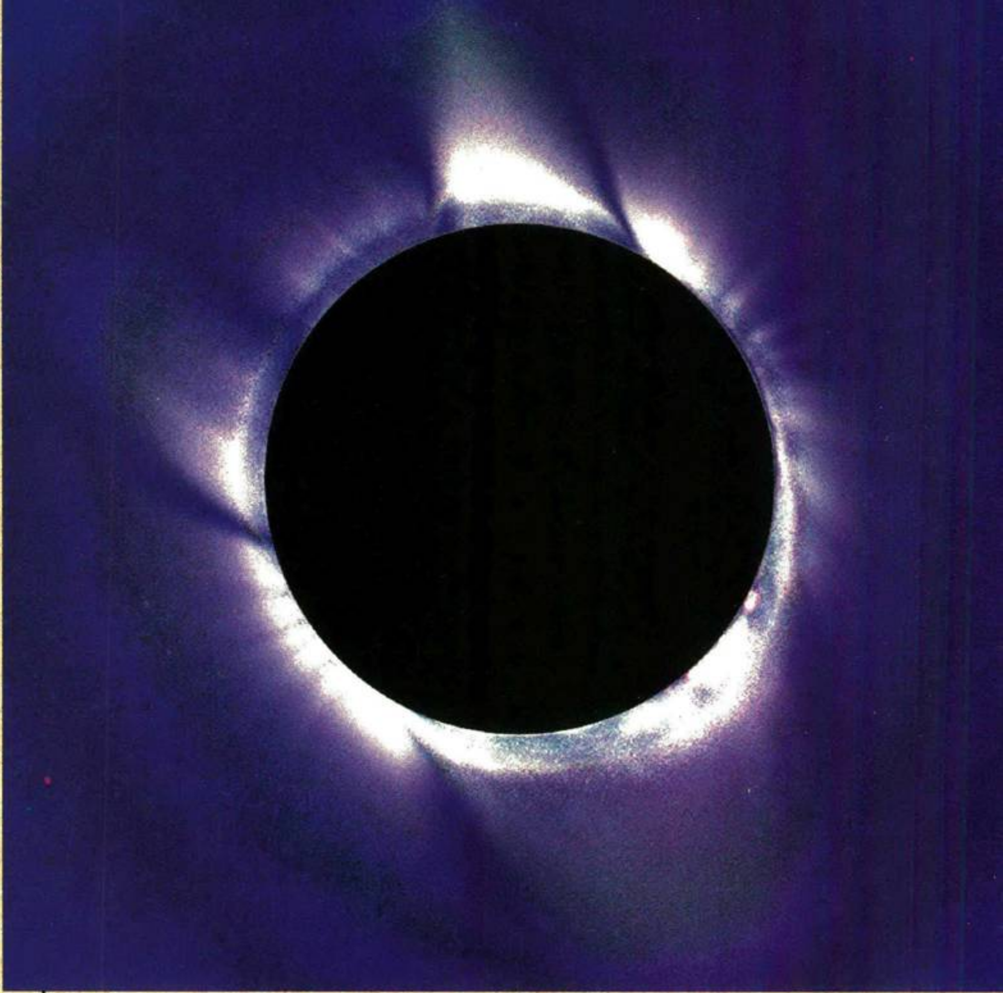
band stretching north-south through the field of the Horsehead. Still no Horshead. He recentered the field, relaxed his eyes, and tried again. Yes, there seemed to be something there, a tiny notch that was ill-defined but seemed to take a bite out of the faintly glowing streamer.

"I've seen the Horsehead!" yelled Kutilek. It was an isolated victory, a lone scream in the night that makes backyard astronomy what it's all about.

Saturn's Edge-on Rings. Everyone's favorite rings have temporarily vanished as Saturn's ring plane crosses Earth's orbit. The result is a strange-looking Saturn in the eyepiece, one that appears vaguely like a distant Jupiter on a night of very poor seeing. Many readers have commented on the planet's peculiar look. Phil Dombrowski of Glastonbury, Connecticut, observing on May 24, 1995, represents the standard comment: "With my 11-inch SCT, I could observe a faint, dark line across Saturn's equator, with no extensions of the ansae visible. The Saturnian moons were quite easily visible. The planet looks more like Jupiter than ever. Faint banding on Saturn's globe was visible during moments of good seeing."

Planetary Marathon. Energetic deep-sky observers have promoted Messier marathons for several years now, attempting to spot all 107 Messier objects in a single evening. Why not do a planetary marathon? Miles Paul of Victoria, British Columbia, suggests trying it the easy way, as he did, when all of the planets were visible during a single night. ☐

ASTRONOMY wants to hear about your observations of the sky. Send reports, sketches, and photographs to David J. Eicher, Reader Reports Editor, ASTRONOMY, P.O. Box 1612, Waukesha, WI 53187. Please label each photo with name, address, and social security number. You may send written reports via the Internet to: rreports@astronomy.com

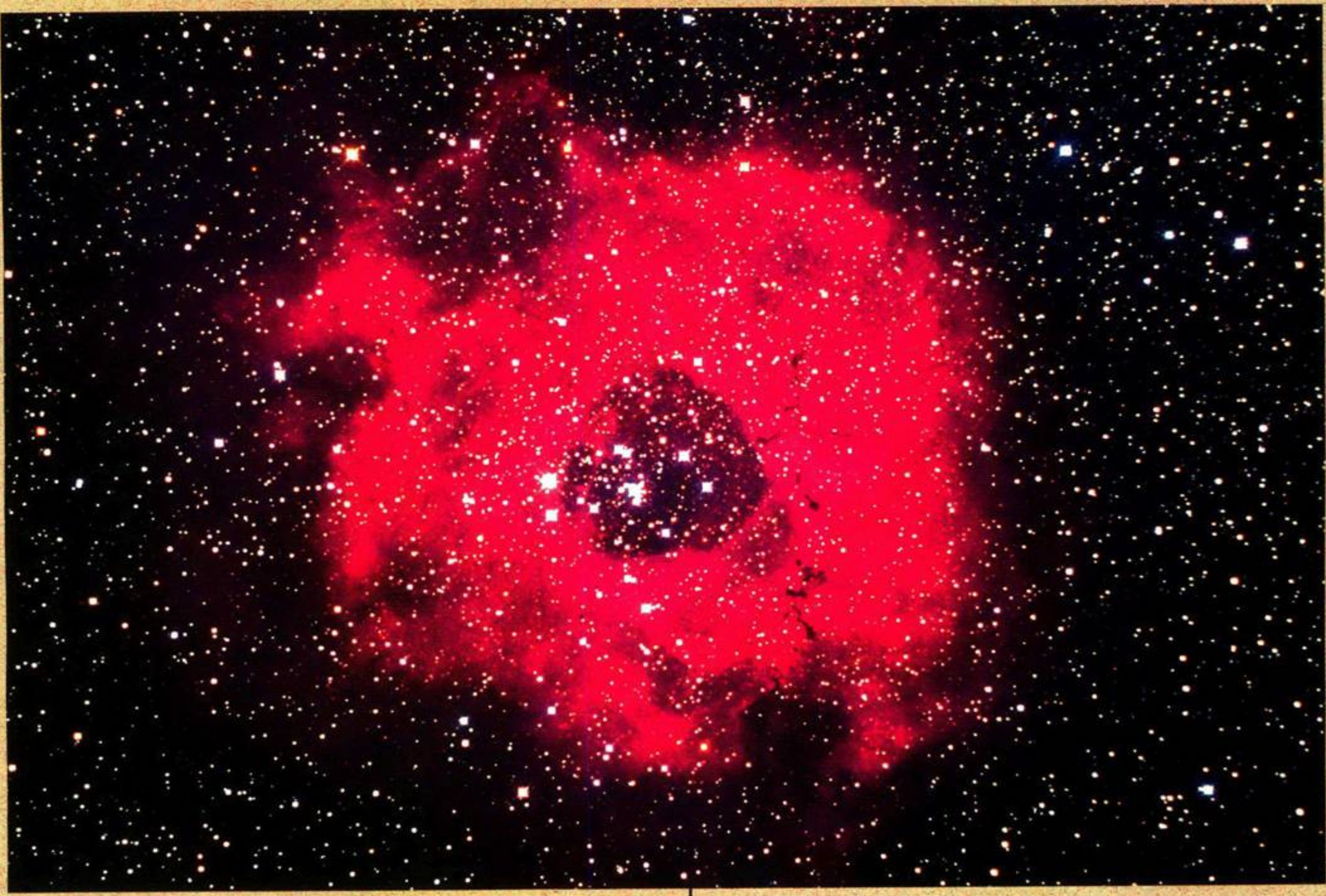


The Total Eclipse of November 3, 1994

by Pierre Guillermier
(4-inch refractor at f/10, composite of five exposures of 1/15 second to 1 second, taken on November 3, 1994, from Chungara Lake, Chile, assembled in Adobe Photoshop)

Shuttle *Atlantis* and Mir Pass Over Hawaii

by Karl W. Bornhoeft
(50mm lens, 1000 ISO film, taken July 4, 1995, from Kailua Beach)

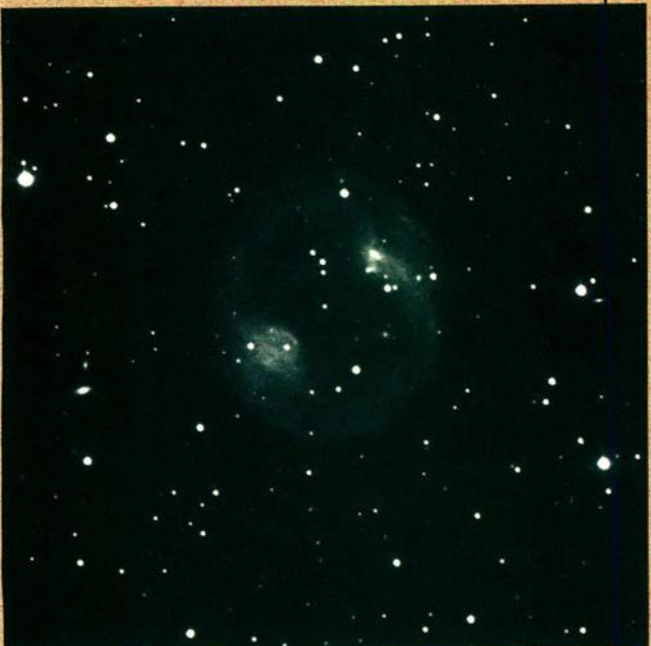


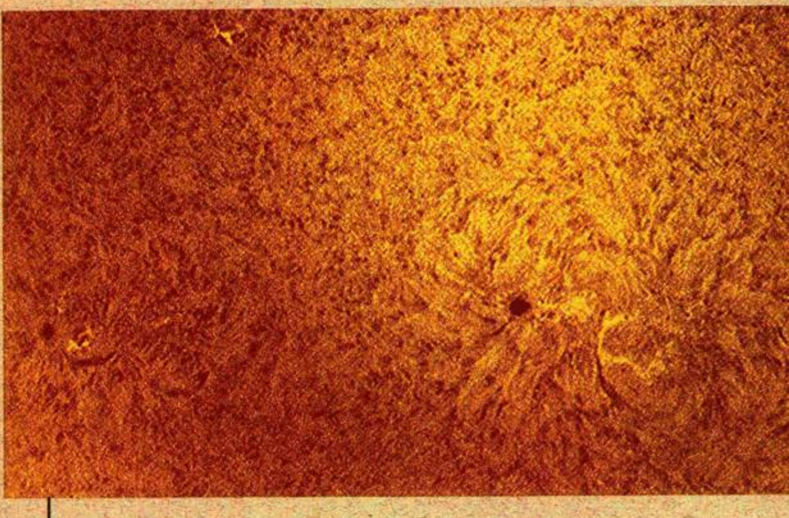
The Rosette Nebula

by Michael Stecker
(8-inch f/4 Maksutov-Newtonian reflector, hypersensitized Fuji Super HG 400 film, composite of two 45-minute exposures assembled in Adobe Photoshop)

Planetary Nebula PK164+31.1 in Lynx

by Martin C. Germano
(14.5-inch f/5 reflector, hypersensitized Tech Pan film, 105-minute exposure)





The Sun in Hydrogen-Alpha

by H.J.P. Arnold
(7-inch f/9 refractor, Tech Pan film, Daystar 0.6Å hydrogen-alpha filter, digitally enhanced in Adobe Photoshop)

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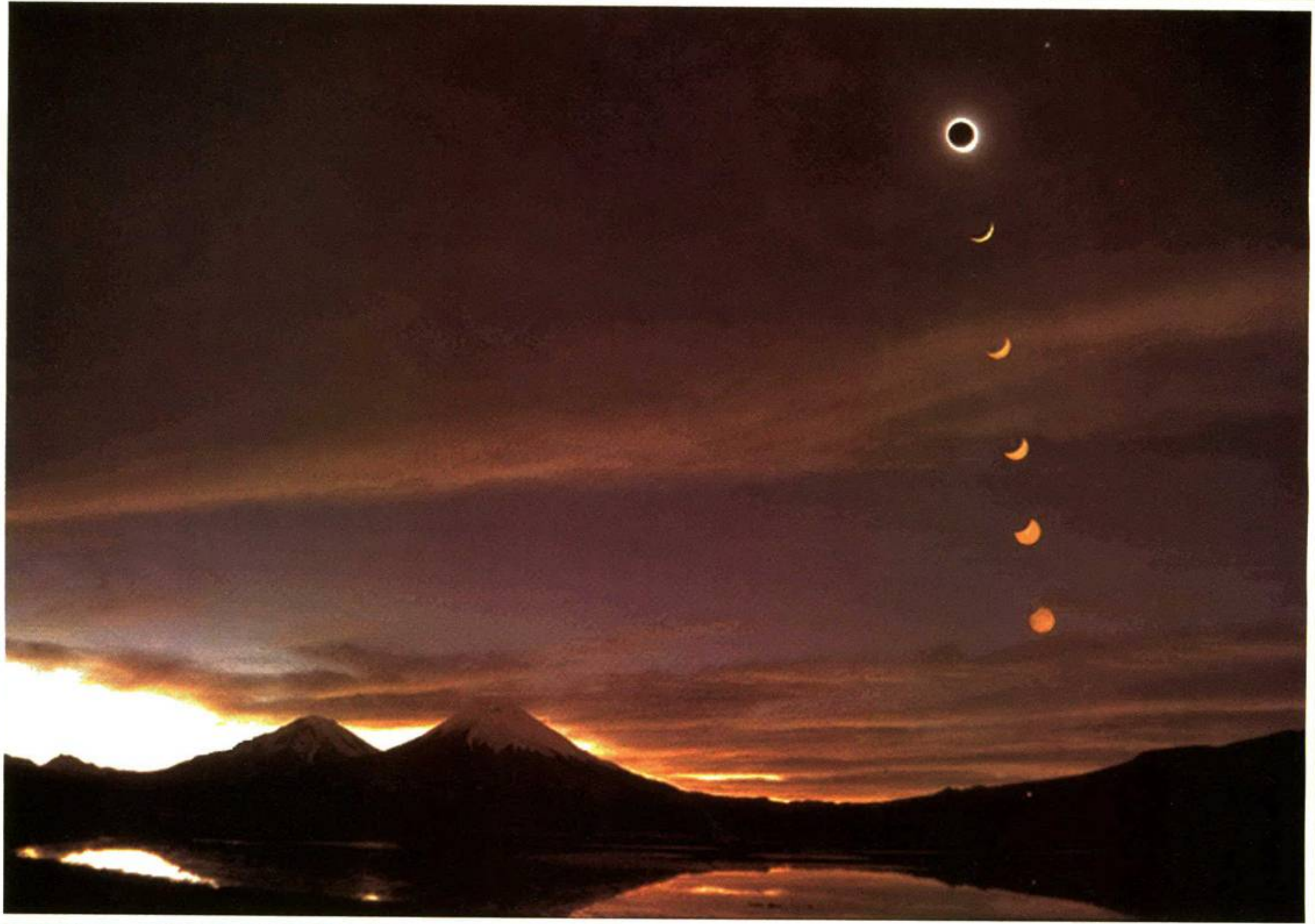

Eclipse Over Chungara Lake, Chile

by Pierre Guillermier

(50mm lens at f/2.8, Kodachrome 25 film, 1-second exposure [foreground image]; 4-inch refractor at f/10, Kodachrome 25 film for partial phases and Fujichrome 200 for totality [Sun images], taken in Chungara Lake, Chile, on November 3, 1994; composited as a single image in Adobe Photoshop)

"I've digitally added these images on my computer to produce a composite of the scene before me and several phases of the eclipse as it progressed," says Guillermier.

"I used relatively slow film for the partial phases and for the background shot and faster film for the image of totality, reduced the Suns to the correct size, and pasted them into the correct spot on the wide-angle photo."

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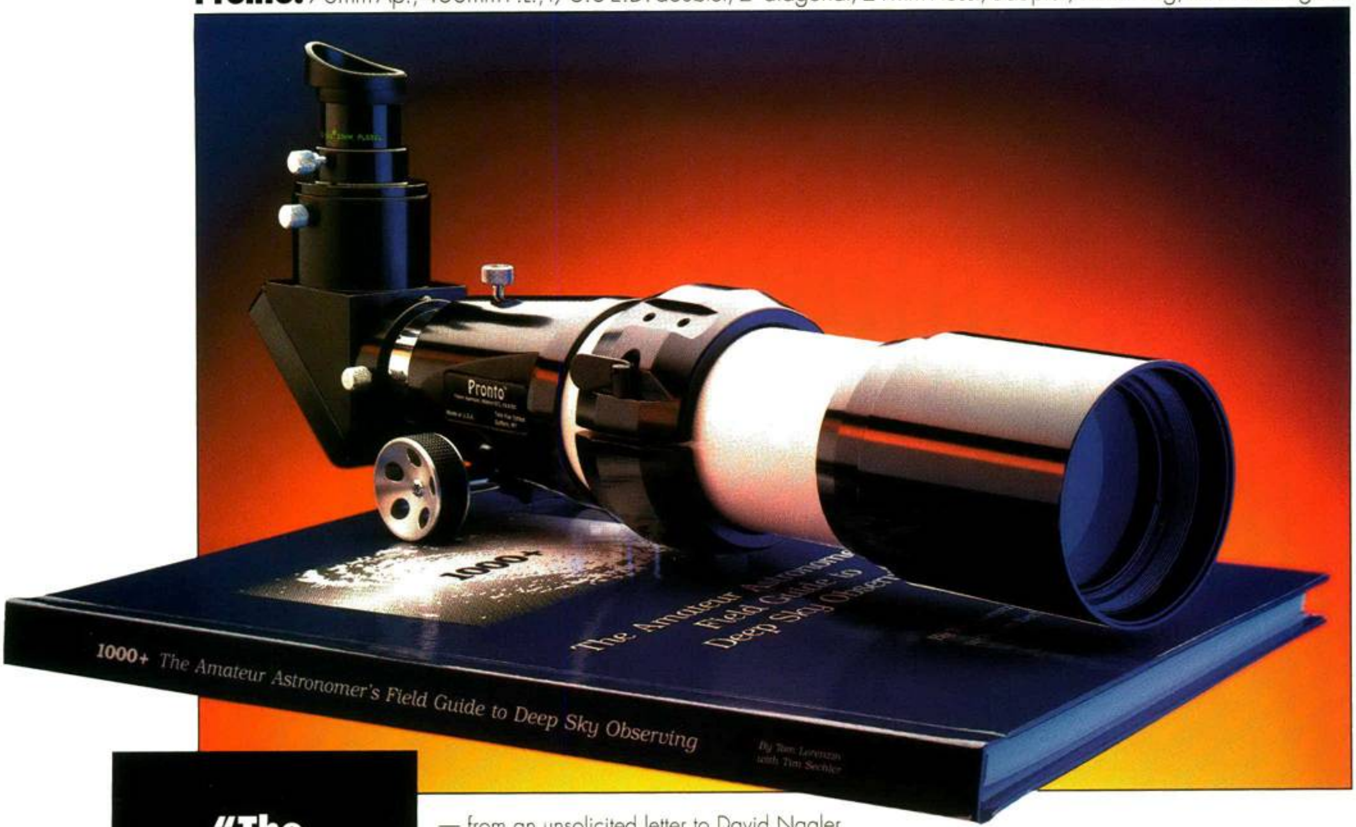
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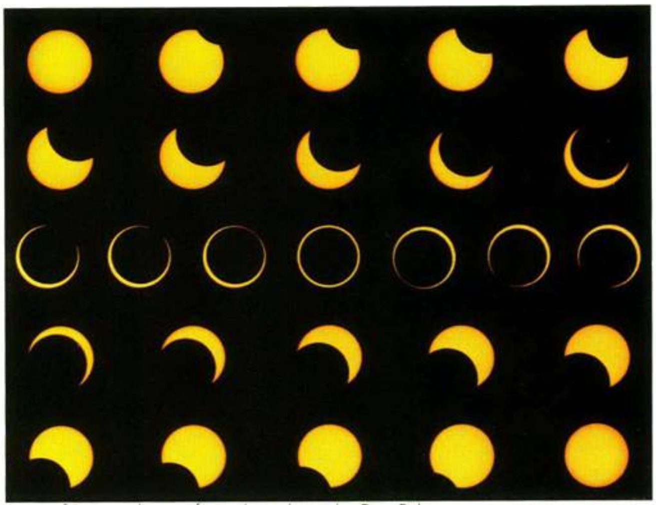
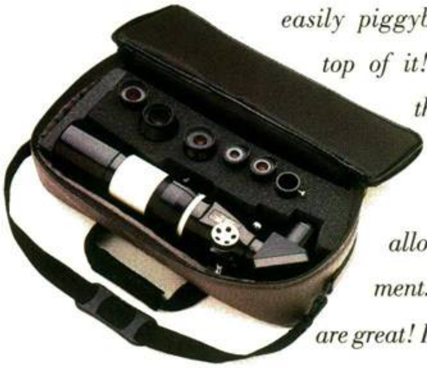


Array of Pronto photos of annular eclipse, by Dan Folz



Best regards and clear skies, — Dan Folz, IL

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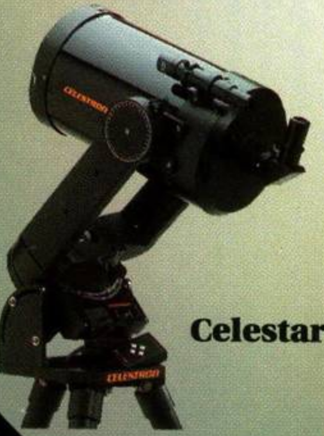

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